The Five Pillars of Effective Curriculum Development

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Literature Review, Practical Analysis, and Applications

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The gender divide in technology, though it has been studied and theorized about for decades, is still prevalent in the twenty-first century (Denner and Werner 2007, Denner, Werner, and Ortiz 2012, Buffum et al. 2016). Many efforts have been made to reach out to young women and bridge the gap between female and male participation in computer science related fields. These initiatives include those undertaken by Drexel University's Entrepreneurial Game Studio (EGS) as outreach to Philadelphia area students. In its most recent iteration, this took the form of workshops offered to middle and high school students from the Greater Philadelphia area.

In order to most effectively and intelligently update curricula for these outreach projects, a review of relevant literature was undertaken looking into meaningful ways to engage learners in new materials. Results from the review were applied to workshops conducted in partnership with the Expressive and Creative Interaction Technologies Center Summer STEAM (Science, Technology, Engineering, Arts & Design, and Mathematics) Lab, the Girl Scouts of Central and Southern New Jersey, and the Franklin Institute's STEM Scholars Program, with the goal to effectively increase interest in programming among middle and high school students, especially girls.

Literature reviewed for this project included works by researchers in the fields of digital media, participatory culture, programming education, introductory game development, classroom education, and adolescent development. Five main concepts: playground, identity, community, confidence, and student position, emerged from the literature and were used to guide the development of the curricula.

These concepts, in the form of five pillars, are as follows:

PLAYGROUND: Students are more engaged when they have the freedom and agency to express themselves creatively and pursue personally relevant projects.

IDENTITY: Students find enhanced meaning in environments where they are free to explore their own identities as individuals; this is particularly true among middle school aged students transitioning from childhood to adolescence on the way to adulthood.

COMMUNITY: Students who are active in a community where they can share creations, receive feedback, and participate in informal peer mentorship, are more interested and personally involved in learning and growing given these supports.

CONFIDENCE: Students who feel competent and confident in their abilities in a specific area are more likely to find learning fulfilling and continue to pursue studies, work, and growth in that area.

STUDENT POSITION: Positioning the student as a protagonist or agent of change provides learning that is more meaningful than does positioning the student in a pupil role as a receptacle for information.

The five pillars are designed to aid in the creation of lesson plans, serving as guides for the development of curricula that promote intrinsically motivated and personally relevant learning. Each will be discussed in more detail below.

THE FIVE PILLARS

I. PLAYGROUND

The idea of a "playground" was coined by Marina Umaschi Bers (2012). Bers notes that children who are put into playpens are constrained by space and the resources defined by their guardians. In contrast, a playground offers children a space to engage in self-selected play (Bers, 2012). She postulates that truly important learning occurs on the playground; the open space requires more active parental involvement due to the increased level of danger, but children are free to interact with others and select which types of play they would like to pursue. She also advocates for content creation as a means to encourage participation and place the student as a "producer" rather than a "consumer." She goes on to describe the comprehension of computational concepts that follows naturally when youth are allowed agency to create their own projects and learn skills as required for those projects' completion.

Yasmin Kafai and Quinn Burke provide further support of Bers' promotion of a free and open space (Kafai and Burke, 2014). They describe the nature of the online community centered around Scratch, a project of MIT's Lifelong Kindergarten Group that serves as a block- and image-based coding environment where users can create games, animations, and interactive stories. Kafai and Burke emphasize that one of the key benefits of Scratch is that users have the liberty to create personalized projects. Based upon interests, users can create artistic animations, "how-to" explanations, or games inspired by past experiences, features touted by the authors. The very nature and success of the Scratch site lies in direct backing of Bers' claim that independent exploration is an important part of learning and mastery of a topic; Scratch's millions of unique monthly visits are a testament to the allure of an environment that allows for user-directed experimentation (Lifelong Kindergarten Group).

Students find experiences more meaningful when they can self-select their projects or areas of work, in the same way a playground where children can play freely is preferable to a space where they are confined to preset conditions.

II. IDENTITY

Identity scaffolding has become an important part of adolescent classroom lesson plans. Much of modern educational literature is based upon the principle that the construction of a self-concept of identity (who one is and how one fits into the world) is one of the key "developmental tasks during adolescence" (Sinai, Kaplan, and Flum, 2012). This principle was explored by Sinai, Kaplan, and Flum in their study of junior high courses. Sinai et al. cite numerous sources that state that education would be "much more effective" if content were integrated with students' personal interests and prior life experiences. This is expanded upon in the study portion

of the paper, where the precept was implemented in a ninth-grade literature lesson. First-person accounts from students following completion of the exercises support the notion that promoting identity exploration enhances a deep and personally resonant understanding of the material, the self, and the relationship between the two.

Bers, in her work on child and adolescent development, places great value on the potential for technology to serve as a tool by which youth can develop their own identities. Identity exploration, according to psychologist Erik Erikson, is a vital part of adolescence (Erikson as cited in Bers, 2012). Digital spaces for tweens and teens ought to be designed with at least some focus on encouraging this inquiry (Bers, 2012). The author presents vignettes of young people who use online environments as tools to discover more about their identities in terms of religion, expand their knowledge of others and their values, and spend time enjoying a common interest. She goes on to declare that teens tend to use online social spaces to "try on" different personalities in the experimental stages of determining their perceptions of themselves.

Bers provides case studies to support individual claims as well as the overarching concept of her book: that digital environments can, and should, be used as tools to promote positive development in youth, and, therefore, encourage the observation, modification, and development of the concept of one's identity.

Furthermore, James Paul Gee emphasizes the importance of the students' perceived identity on the effectiveness of their learning (2007). He theorizes that students who already possess a tie to the topic they are learning or strong self-confidence in their ability to pick up new concepts in that area are at a great advantage in the presented domain. He states that the perception of "capacity" empowers a student to adopt traits from this "virtual identity" (using the example of a middle-schooler in a science class adopting some of the characteristics of a scientist) into his or her real-world identity and experience a deeper and stronger connection to the content being taught.

Putting this concept into action by promoting individual exploration and development of a self-concept that reflects confidence in the subject manner will guide students toward self-perceptions of aptitude and encourage contemplation of the material as a basis for potential pursuit of a new interest in upcoming years.

III. COMMUNITY

There is a vast body of research supporting the importance of a learning community or "affinity space" in the comprehensive education of a learner (Gee, 2007). Communities, declares Bers, are vital to social and personal development, given their focus on interpersonal interaction. Kafai and Burke outline the atmosphere in "computer clubhouses," where students who worked on projects after school would frequently swap computers to show off their work or excitedly call out to one another upon the discovery or creation of a new feature (2014). This principle extends into another discussion of the Scratch website, a project of the Lifelong Kindergarten Group at MIT's Media Lab. One of the most important facets of the Scratch site is its wide user base, which fosters cooperation on projects: for example, one user might create art for a game, another, do the

"programming" using Scratch's block-based engine, and a third might provide conceptual direction and oversee collaboration. Kafai and Burke note that the online Scratch community proved widely helpful in promoting exploration and learning, especially in that it allowed users of all ages to ask one another questions and offer advice in specific fields of Scratch expertise, allowing all to grow in a space that promotes a shared interest.

Catherine Beavis, in a 2013 study of technology use by Australian youth, investigated the massive, viral success of the "Dumb Ways to Die" campaign through allowance for remixing. Her work highlights the vast importance of communal activities to digital participants (Beavis, 2013). This is echoed in Scratch's popular "remix" feature, where users can edit and build upon the work of others to create new, hybrid products (Kafai and Burke, 2014).

Gee, too, touches on the importance of "affinity spaces" in learning, detailing the exchange between "external" content (interactions and information exchanged within a certain community) and "internal" content (interaction with and internalization of these concepts on the individual's part). The author defines a "semiotic domain" as "an area or set of activities where people think, act, and value in certain ways" (p.19), and further explains that these domains exist in spaces in which communities of people share ways of thinking, evaluating, or approaching a certain topic. Individuals involved in these spaces experience organic learning as they prepare to take part in a domain. Gee states in his "Semiotic Domains Principle" that participation in these spheres is vitally intertwined with learning as a whole.

Jenkins, Clinton, Purushotma, Robison, and Weigel (2006) build upon the work of Gee, distinguishing informal "affinity spaces" from formal educational spheres by their innovative and experimental nature and the ability of the user to freely enter and exit. In addition, the authors cite other works in support of Gee's theses, stating that "editorial feedback" (p.9) and constructive criticism offered in an area where all members share a common interest can help to further the knowledge and skills of all.

Articles by Denner and Werner (2007) and Buffum, Sheridan, Frankosky, Boyer, Wiebe, Mott, and Lester (2016) support the concept of pair programming, particularly among the target demographic of middle school aged girls. This practice, where students work in groups of two to complete a task, embodies a specific sub-item of the "Community" pillar. Here, students have access to a larger community (typically including peers and an adult facilitator), but work with just one other individual. Though this may appear at first to be a small and restricted community (with only two primary members), this approach to collaborative problem-solving emphasizes the importance of external supports, sounding boards, and mentorship. Recordings of pair work on developing interactive games created during Denner and Werner's 2007 study highlights the nature and critical importance of interaction with other parties during the development and debugging processes. Students were most likely to work with their paired partners to solve problems, more likely than they were to either ask the instructor or to ask for help from other pairs.

Buffum et al. (2016) utilized this concept in their study of middle school Computer Science Principles courses, investigating the effects of pair programming (using a game-based learning environment focused on block-based coding) on the gender gap in understanding at the start of

the pilot study. The researchers found that this collaborative experience may have helped to minimize the gaming experience gap -- students who played games infrequently and were less familiar with in-game strategizing could be helped by their more-experienced counterparts and find more efficient ways to complete tasks. Students involved in the pilot study also reported the benefit of being able to use their partners as "sounding boards," which highlighted the importance of other individuals being available for feedback on and improvement of ideas. Furthermore, the full study conducted by Buffum and colleagues proved that students who scored lower on a pre-test (i.e., those with lesser initial knowledge of concepts in the subject area) exhibited greater learning gains, confirming the hypothesis that pair programming proved effective in minimizing the disparity in initial proficiency exhibited by students.

Both in pairs and wider-spread communities, learners in the target demographic have demonstrated and exemplified the effectiveness of this approach. Its effects have been studied and proven time and again, and allowing students to reach out to others for support provides for highly expanded learning opportunities and enhanced connection of ideas and interpersonal thought.

IV. CONFIDENCE

Marina Umaschi Bers champions the idea of improving student confidence through the creative use of technology (2012). Additionally, Bers highlights the vitally interconnected relationship between competence and confidence. She states that the two concepts regarding individual self-perception and actual ability to carry out tasks in a domain support one another -- a person who believes herself competent in a particular area will be self-assured enough to pursue further exploration into that subject matter. Meanwhile, according to Bers, a student who is confident in his abilities to learn in a particular area will pursue further skills and competence in that field. Thus, according to Bers, these two interconnected items feed and support one another as the individual progresses through his or her knowledge of any given topic (in this case, technological fluency). Bers tightly links the concept of confidence to progression through a project or educational system, stating that self-efficacy leads to a belief in one's own ability to learn new topics, and thus creates internal motivation to pursue an interest.

James Paul Gee pursues this even further when discussing his "Identity Principle" (2007). He uses the analogy of a student in a science classroom taking on the "character" of a scientist and its importance in the student's self-evaluation of his or her capacity to learn and understand scientific texts and concepts. A student that already possesses self-developed notions of identity that lie in opposition to this identity will have much greater difficulty engaging with the presented scientific material. One conclusion that can be drawn from Gee's and Bers' postulates is that students display deep engagement when they believe themselves capable of further learning in the presented subject area. To fully immerse students in pursuing a particular topic, one must support the development of self-perception of competence in the relevant field.

Both Bers and Gee present their ideas in the context of student self-efficacy, defined by psychologist Albert Bandura as "beliefs in one's capabilities to organize and execute the courses of

action required to produce given attainments" (1997, p. 3). Bandura, in his 1997 work on self-efficacy and its effects on learning, synthesizes myriad studies and notes the correlation between belief in one's ability to complete tasks in a field and achievement in related areas. Bandura goes on to state that "efficacy beliefs predicted interest in, and positive attitudes towards," the subject studied, "whereas...ability did not" (1997, p. 215). This claim is backed by citations of studies from Bouffard-Bouchard, Parent, and Larivée (1991), who provided evidence for the causal relationship between sense of self-efficacy and "cognitive performance" (as cited in Bandura, 1997 p. 215) noted in a graph of trends where students at all ability levels with high self-efficacy performed better than their equally-competent peers with lower confidence. What is perhaps more relevant here, however, is Bandura's statement about interest and attitudes as a result of this confidence. One of the key aims of the Skyscraper Games workshops is to increase student interest (particularly among girls) in computer science, game design, and related fields of study. Thus, the workshop curricula designed to boost student confidence in computing and computational concepts can be expected to improve attitudes towards the area and aid in the achievement of the goals of this outreach project. Additionally, Bandura proposes the teaching of accessible subskills as a means of incremental education towards improved self-efficacy.

Psychological and programming-education based evidence supports the improvement of attitudes and performance resulting from processes designed to improve internal conceptions of capability. Additionally, the use of incremental "small bites" has been outlined as a potential solution for students who require additional building of self-perception of competence. This translates to the use of numerous lessons that focus on individual concepts as a way of building confidence and encouraging a positive self-image with regards to computing and computational thinking abilities.

V. STUDENT POSITION

Barab, Pettyjohn, Gresalfi, Volk, and Solomou (2012) investigated the effects of interactive student-as-protagonist methods of instruction compared with those of more traditional methods. A section of students learning about persuasive writing was split into two groups, each of which were taught using one of the two outlined methods. The first group learned through discussion and work surrounding a text; the second played a game in which they could make decisions and review and evaluate the outcomes of those decisions. After the lessons had been completed, students took a posttest. While both groups exhibited clear learning gains, the group positioned as protagonist (those playing the game) displayed significantly greater gains in mastery of the concepts taught. In addition, when asked about the motivation to complete tasks, the students who participated in the interactive environment were far more likely to have been motivated by the task itself, an indication that positioning the student as agent of change improves active engagement with the material.

Though Bers never mentions "student position" in name, many of the approaches developed in her 2012 work heavily involve the placement of the learner at the helm of his or her own experience. She states that youth should be given a significant degree of control over the way

they participate in digital cultures. Additionally, the author advocates for the development of projects as a vehicle for learning and comprehending both technical and non-technical ideas. She proposes allowing students and learners to "make their own way" and experiment with social, personal, cultural, and communal learning in the sort of low-risk environments afforded by the technology of the digital age. Her work focuses on the ways young people interact with their virtual environments, nearly assuming that the student or learner is "in the driver's seat." By basing the vast majority of her assertions on this principle, Bers implies the fundamentally necessary nature of positioning the student as creator of, agent of change in, or other active contributor to his or her own learning.

A.J. Juliani (2014) is also a heavy proponent of this ideal; he outlines to his readers (particularly those who are educators) the ways project-based learning can be implemented in classrooms. His claims are backed up by the practices of heavy-hitters in innovation such as Montessori schools and Google. He proposes implementing student-driven investigation in the classroom as a way to prepare children from preschool to high school for the new "real world" that has emerged in the twenty-first century. He also builds upon Buffum et al.'s concept of intrinsic motivation, noting that personal passions are far more effective incentives for student success than are external factors such as grades.

Engaging students means supporting their individual interests and allowing them to be in charge of their own educational path (at least to some extent); this process, in turn, encourages students to be fully involved in the subject matter they are exploring and maximizes content comprehension and retention.

ANALYSIS OF ONLINE ENVIRONMENTS BASED ON FIVE PILLARS

After the Five Pillars were drafted, additional analysis aimed to validate the existence of these concepts in established online programming education environments. These environments were determined through an online search and general investigation into their usefulness and appropriateness to the purpose of the study by the researcher. The pillars were broken down into three levels of characteristics for which the nine selected modules (Grok Learning, Code.Org, Codecademy, Computer Science Circles, CheckIO, Learn Python the Hard Way, Ask Python, Code Combat, and Learn Python) could be evaluated. The levels are as follows:

Playground:

Level 1: A "sandbox", such as a code environment with a "run" button available in-browser, is included as a place where the user can test code and experiment with concepts.

Level 2: The environment offers a variety of paths the user can take dependent upon specific interests or individual needs.

Level 3: The environment offers a space for the user to develop a personal project and explore subject matter without an imposed structure.

Identity:

Level 1: The module offers the sense of a sphere where information is accessible to the novice and implies that the beginner is capable of taking a space in the arena.

Level 2: The curricular structure and progression encourage the user to think of him- or herself as a programmer.

Level 3: The challenges presented to the student offer opportunities for the student to develop independent, original solutions and assume self-leadership in problem solving.

Community:

Level 1: The online environment is structured such that the student can access tutorials or instruction from others.

Level 2: The environment offers a space in which the user can mentor and exchange information with peers.

Level 3: The website includes a format and space in which the user can create a personal project and share his or her completed work with others.

Confidence:

Level 1: The module provides transparency for the opaque subject matter and makes the material accessible and understandable to the newcomer.

Level 2: The lessons include challenges that promote incremental growth.

Level 3: The units provide prompts that make the user feel challenged but capable, and encourage original, independent problem-solving thought.

Student Position:

Level 1: The environment offers the user embedded opportunities to try his or her hand at coding amidst the presented instructional content.

Level 2: The prompts allow the student to write his or her own program, in its entirety, or use an original solution rather than being fed one particular procedure.

Level 3: Within the website, the student can generate original, creative, unfettered code outside the context of an exercise.

Each of the selected environments was investigated to its unit on conditional statements, and the evaluations were charted as follows:

Level	Not Present	Level 1	Level 2	Level 3
Charted Color	**0**	**1**	**2**	**3**

	Playground	**Identity**	**Community**	**Confidence**	**Student Position**	**Adherence (Total/15)**
Grok Learning*	**2**	**2****	**2*****	**1**	**2**	**60%**
Code.Org****	**3**	**1**	**3**	**1**	**3**	**73%**
Codecademy	**2**	**2**	**1**	**2**	**1**	**53%**
Computer Science Circles	**1**	**3**	**1**	**3**	**2**	**68%**
CheckIO	**2**	**3**	**2**	**3**	**2**	**80%**
Learn Python the Hard Way	**0**	**2**	**0**	**2**	**2**	**40%**
Ask Python	**0**	**3**	**0**	**3**	**2**	**53%**
Code Combat	**2**	**2**	**2**	**2**	**2**	**67%**
Learn Python	**1**	**3**	**0**	**3**	**1**	**53%**
Combined	**13**	**21**	**11**	**20**	**17**	
Mode	**2**	**3**	**0,2**	**3**	**2**	

*This environment was only evaluated through the second module, Calculations, because beyond that point was paid content and this survey was focused on freely available resources.

**There appears great potential for Level 3 here, but it is located behind a paywall.

***Opportunity exists in the form of a forums space but no forums currently exist.

****This resource was not Python-specific but instead used a block-based format to appeal to young learners.

Percent values were rounded to the nearest whole percent.
The average adherence is 61%.

The conclusions drawn from this portion of the research indicated that the analyzed modules were strongest in supporting identity exploration and student confidence, and often lacking in the community aspect. However, the distinct presence of each of the five pillars (all of which scored at least 10 out of 27 points) proves that all are used within the sphere of online coding education, and proves the validity of these five pillars for use in this arena and others with related aims. Additionally, the relatively mediocre adherence values (the majority of which fell between 50 and 69 percent) reveal the existence of a niche for a website that fully exhibits all five pillars. The Skyscraper Games Website, designed to accompany the workshops and their curricula with coding lessons, could easily fill that niche.

APPLICATIONS IN PROGRAMMING WORKSHOPS

The primary application of this research was the modification and improvement of workshop lesson plans for EGS-hosted events. The curriculum underwent several renovations over the course of the summer and the latest iteration at the start of the ten-week period was adapted for three different workshop contexts. The first was a two-day, four-hour-per-day workshop with girls aged 11-15 in partnership with the Girl Scouts of Central and Southern New Jersey. The second was a one-day, three-hour session for middle school students from West Philadelphia taking part in the Summer STEAM program at Drexel University's Expressive and Creative Interaction Technologies (ExCITe) Center. The third was a two-day, four-hour-per-day workshop offered to high school students involved in the Franklin Institute STEM Scholars program.

Though the same core concepts and framework were utilized throughout each workshop, the specifics, content, and activities were adapted for specific usage and age level. For example, the shorter time requirement for the Summer STEAM session necessitated a reduction of content to fit within the three hours allotted for the workshop. The "brain breaks" (structured "unplugged" activities intended to give participants a brief respite from coding while still encouraging algorithmic and/or critical thinking) offered throughout the day for students were modified to suit the age of the participants -- younger students played active games such as Simon Says, while the older students were engaged with structured thinking activities such as arranging themselves in height order without talking.

Additionally, specific changes to the existing structure were proposed. A short list detailing the curriculum in the context of the Five Pillars was drafted. The format used for the most recent iteration of the Girl Scouts workshop was reviewed, and the points of the curriculum that supported each pillar were listed. Notable strengths included: the "Playground" pillar, which was demonstrated in the ability of students to create their own character art and design original games for the world's largest architectural video game display, and the "Confidence" pillar, which was embodied in the incremental and spiraling lesson structure and the presence of numerous adults to support individual challenges and struggles. The workshops were strongest in the "Student Position" area, supported primarily by the hands-on nature of the entire workshop that allowed for participants to be in control.

Though the preexisting workshop curriculum included elements that strongly fulfilled all five pillars, some additions to the workshop design were conceived, developed, and suggested to further strengthen the program. Three primary additions were proposed:

I. Applications Discussion
    - This segment, designed to support the "Playground," "Confidence," and "Identity" pillars, is intended to put the topics that participants learn into the context of their everyday lives. The segment is broken into two parts:

- The first is part of the introduction to the first day of the workshop. Students are asked to brainstorm both the obvious and subtle ways that computing affects their daily lives and name common items that are powered by code, such as video games and programmable coffeemakers. This will serve as a reminder of the myriad opportunities available to those who learn to program, and as a point to consider throughout the lessons -- prompting students to consider, at each step of their coding journey, the applications for which they personally might like to explore their new skills.
- The second is offered at the very end of the "hands-on" section of the workshop(s), immediately before the reflection and posttest portion of the final day. It is intended to recontextualize computational thinking and the skills, not only in coding, but in **learning to program** that the students have accumulated since beginning the workshops. Here, participants will be invited to reflect on what they would like to do with their new knowledge. They will be reminded that, not only have they learned many key concepts in programming, but that these, as well as learning **how to learn to code**, can and will construct the framework they will need to pursue computing in any field or avenue they would like.

II. How Would…

- These exercises serve as further curricular backing for the "Confidence," "Identity," and "Student Position" pillars by placing students in the role of critical thinking problem solver.
- This is achieved by inviting students to contemplate the functions of specific programmatic concepts and prompting thought that promotes deep understanding of principles taught.
- During the instructional period, participants will be offered a hypothetical challenge to contemplate and attempt to solve, either as individuals or as a group.
    - These tasks are designed to promote contemplation of the relevance of specific, individual topics as well as algorithmic thinking.

III. Share Out

- This suggestion takes the form of reserved time at the end of each workshop day and is planned to bolster the "Community" pillar that already exists in the forms of table groupings that encourage collaborative problem-solving and roundtable discussions for feedback regarding student-generated game ideas.
    - Here, students' created pixel images (Day 1) and finished Game Design Documents (Day 2) will be (optionally) shared among the group, gallery-style or presentation-style.
    - Participants will gain the experience of presenting their ideas to a group (and thus, the satisfaction of showing off a finished product), as well as the

benefits of the sharing of information in seeing others' original ideas and any resulting inspiration.

THE FIVE PILLARS IN DIGITAL ENVIRONMENTS

Educational games served as a distinct portion of both the body of research and its originally proposed outputs. However, certain elements are often overlooked or overshadowed by the desire of creators to generate interest by promoting a "game" that is modeled after recreational games. This approach, while certainly somewhat effective in generating initial interest on the part of the user, does not account for components of other learning activities that interest their participants. Games are one way to draw intrigue, but are by no means the only way of inspiring users to pursue a certain end. Thus, a better frame of mind surrounding works of digital media designed for education is one centered on *environments* rather than just *games*. This opens up a plethora of opportunities outside the mechanics of a typical "game" and, therefore, broadens both the applications and the opportunities to include engaging features from a more varied selection of tools.

The following are proposals for design aspects of a digital environment that promotes engagement unrestricted to the facets of a game. Pillars supported by each are offered in parentheses at the conclusion of each description.

I. Sandbox:

- Many of the programming websites studied as part of this research included a space where users could write and test their own code. As a broader principle, this refers to the existence of a space for the testing of concepts and/or original ideas.
- This may take the form of:
    - Simulations (for example, a simulated circuit board for the testing and exploration of setups that eliminates the cost of actual materials)
    - Creation environments (for example, built-in photo editing software for a graphics course where menus and capabilities tie in directly to the offered content)
    - Sandboxes for code or text.
- (Playground, Identity, Confidence, Student Position)

II. Projects:

- Individual, personally relevant projects offer a marvelous vehicle for teaching. Though there may be some limitations on the nature of the final product given that the project must utilize concepts in the taught discipline, this type of project-based learning (PBL) creates the opportunity for transdisciplinary study and increased personal significance to the learner.
- This, in turn, creates an experience that is meaningful and memorable, and invests the user in significant learning situated within individually determined interests.
- (Playground, Identity, Confidence, Student Position)

III. Pathways:

- Along similar lines, most disciplines can be broken down into smaller, more specific topics that may offer pathways appealing to a variety of learners.
- By dividing large topics with overarching learning targets into smaller, more specific subjects that fulfill those aims, educators or other developers can invite their users into individually intriguing exploration, enhancing student commitment to the presented content.
- (Playground, Student Position)

IV. Forums:

- External support in the form of participation in peer mentoring relationships can prove extremely beneficial to bolstering student learning.
- Online forums, or similar platforms, allow for a great deal of interaction between users of all ages, abilities, and interests. Similar to the way gaming forums, these can offer a sense of:
    - Support in learning (for example, walkthrough posts and boss battle tips)
    - Social acceptance and friendship (in the form of news, social exchanges, and "geeking out" over various topics)
- Both the technical and social facets of these interpersonal interactions prove effective in supporting exploration of new topics by participants, backed by the research of Bers, Kafai and Burke, and others.
- Including moderated forums in **or** about an instructional digital medium will provide those involved with opportunities for:
    - Questioning
    - Feedback
    - Building of expertise in a personally selected topic or subtopic
    - Participating in mentoring relationships with a diverse group of individuals.
- (Identity, Community, Student Position)

V. Gallery:

- A framework that allows for the creation of student-driven projects and project-based learning supports the tandem usage of a means to present such products. Users will find great satisfaction in having completed a deliverable that can be presented to the greater community.
- This, in turn, opens up these creations to feedback (which, while potentially negative, can be monitored to encourage and allow only that which is constructive) that can greatly improve users' confidence and provide them with individually-tailored suggestions as they progress to revisions or to another project.

- (Identity, Community, Confidence, Student Position)

VI. Increments:

- The concept of the Zone of Proximal Development (ZPD) was originated by psychologist Lev Vygotsky, who theorized that learning occurs in the "space" between the tasks a learner can accomplish unaided and those he or she cannot accomplish at all. Therefore, the ideal lesson targets those tasks the learner can complete with some degree of assistance (Sanders and Welk, 2005).
- This can be achieved in lesson planning by designing each module in incremental segments -- if each individual lesson builds on the previous one, students will not feel underchallenged (bored) or overstretched (frustrated) and will experience learning in the ZPD.
- (Identity, Confidence)

VII. Simplicity:

- Accessibility of information is vital to pulling learners in.
    - Technical jargon or other unfamiliar concepts can overwhelm users or scare them away.
- Part of building confidence and allowing for identity exploration includes breaking information into manageable segments and making those parts readily understandable by users with the anticipated background.
    - Incrementally-based lessons can (and should) build upon previous lessons and reinforce topics taught in each
    - New information presented should be described at an introductory level such that it facilitates foundational understanding.
    - Introductory lessons should be styled such that a newcomer feels able to understand the content and proceed through subsequent lessons without feeling lost or like an imposter in the area.
- (Identity, Confidence)

VIII. Challenges:

- One way to increase student confidence is by encouraging the satisfying feeling of having solved a problem with an originally devised solution.
- Providing prompts, challenges, or problems that allow for multiple methods of solving promotes deep knowledge of the subject matter as well as overarching critical thinking skills that encourage original thought, problem solving, and adept manipulation of all parts of the subject matter.
- (Identity, Confidence)

IX. Extensions:

- Support of individual passions or areas of interest provides reinforcement of both the relevance of the subject matter and its importance to the individual.
- Thus, providing links to either additional internal **or** external resources can provide contextualization important to keeping a learner's interest.
    - Some of these should be specific to various subtopics, such as "Java for Game Development," "Java for Mobile App Creation," and "Java for Simulation Software."
- Additionally, extending the learning materials to outside resources means that diverse learning styles can be accommodated without additional extensive research and work on the part of the developer.
- (Identity, Confidence)

THE FIVE PILLARS IN CLASSROOM ENVIRONMENTS

Though the five pillars were developed for a time-restricted, two-day set of workshops, they were designed with much broader applications in mind, one of which being classrooms at all levels serving every kind of student. As a supplement to the Five Pillars themselves, a guide to the Five Pillars In Action was designed to assist in implementing these ideas in diverse classrooms.

Playground:

- ❏ Students are allowed time in the classroom (real or virtual) to pursue individual projects.
- ❏ Students are provided with structured free time in which they can explore taught concepts individually.
- ❏ Curricula and lesson plans are structured to be adaptable in the direction of student interest.

Identity:

- ❏ Students are offered the opportunity to lead their peers in learning.
- ❏ Information is broken down to manageable components and presented in an accessible manner.
- ❏ Students are able to devise original solutions to prompts and problems.

Community:

- ❏ Students are permitted to offer each other advice and participate in peer mentorship.
- ❏ Students have the opportunity to work in groups and collaborate during the problem-solving process.
- ❏ Students are presented with the opportunity to share their personal successes with their peers

Confidence:

- ❏ Information regarding what was taught as well as extended learning are readily available.
- ❏ Challenges posed promote incremental, spiraling growth.
- ❏ Students are encouraged to pursue independent, original solutions to the challenges and problems posed.

Student Position:

- ❏ Students have the opportunity to present their own work and lead their peers.
- ❏ Students are promoted in self-guided learning within subtopics of the main content.
- ❏ Course and lesson plans can be modified within the content to adapt to student goals and interests.

DISCUSSION AND CONCLUSIONS

The body of publications regarding educational games and successful computer science education, particularly in middle school students and especially in girls, is conclusive and cohesive. The scientific community based in this field advocates for encouraging student involvement through myriad approaches that can be summarized in five key points, or pillars. These can be applied to aid in the development and refinement of curricula for both online and classroom courses on any subject. These Five Pillars are supported by analytic research of existing instructional programming, which serves as concrete proof of their relevance while indicating the presence of a niche in the world for an online learning environment that fully embodies the qualities of all five.

But the Five Pillars are designed with far broader purpose in mind. They provide a widely applicable basis on which educators and other designers of learning spaces and structures can build successful curricula. Means to support engagement include project-based learning, incremental lessons, community feedback, and collaborative study. The extension of these concepts into the digital sphere means rethinking what a virtual learning environment ought to be, and what elements it should include, such as sandboxes, forum spaces, and extensions of content.

The applications of these pillars in education are extensive. They exist as research-backed foundations for the modifications made to real-world workshops. A substantial body of research, including study on both the theories and applications relevant to the field provide secure backing for this plan. However, they were designed for far wider applicability, and thus extend to use in both the traditional and digital classroom.

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