A G-READY model to support subject design for Software Engineering

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Abstract

This paper contributes to Scholarship of Teaching and Learning by proposing a dynamic model to support subject design for Computer Science during the current Coronavirus pandemic. The proposed G-READY model borrows from the greedy algorithm, which can support quick and efficient transition of subject teaching from F2f to online mode and vice versa in the most economical and time efficient manner. This model aims to deliver adaptable, optimized learning experience to students within shortest possible time frame. The paper also offers a support repository of learning and teaching tools that can help the faculty with designing their subjects with minimal effort spent on exploration for resources. This open source repository is aimed to bring efficiency to the process of curating effective learning and teaching resources for computer science teaching and can be extended further. The G-READY model proposes a learning design that is insightful, reflective, dynamic and learning supportive.

Keywords

Learning, teaching, SoTL, active learning tools, repository, computer science

1. Introduction

The COVID- 19 pandemic affected populations worldwide and its effects will be felt for many years to come. People, regardless of their race, religion, nationality, economic status and gender have felt the impact of pandemic in all aspects of their lives. Sadly, the effect has been more profound for the most vulnerable in our societies- the old and the young populations. While on one hand, the pandemic has severe health consequences for the aged population, it has created uncertainties for the young, majority of whom are students, by disrupting the most stable and essential part of their life- schooling.

Most governments around the world took conscious decisions to temporarily close down the educational institutions in an attempt to contain the spread of COVD-10 pandemic [1][2]. The school closures in 188 countries heavily disrupted the learning process of more than 1.7 billion children and youth [2]. With nearly 80% of the world's enrolled students not being able to continue education through traditional means, educational institutions responded by providing students with learning opportunities via online and distance learning [3] in order to prevent a learning crisis.

Though, for many years now, blended mode of learning has become increasingly popular [4], the suddenness with which the institutions were expected to convert lesson delivery to full online mode became a big challenge for the educators. In order to mitigate the impact of school closures due to Pandemic on students' learning outcomes, higher education providers redeveloped curriculum for online offering [5].

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Caught unawares, several institutions initially focused on transition of teaching to online environment and overlooked the online pedagogy and the student learning experience [5][6]. The unprecedented circumstances created by COVID-19 gave very narrow preparation window to the teaching faculty to improvise their teaching methods in order to have successful learning outcomes in a fully online environment. The sudden and staggering shift in teaching mode was considered test of organizational agility [7], and brought the digital readiness of the higher education sector under scrutiny.

Unlike the traditional face to face teaching, online learning and teaching involves a diverse range of educational tools, resources and pedagogical approaches [8] giving resources and opportunities to wow the learners. However, online learning and teaching imply not just use of internet to deliver lessons but also an awareness of pedagogical content knowledge [9]. We have to acknowledge the fact that quality of learning is significantly influenced by the instructional strategy and not the learning technologies. The instructor has to be mindful of using a blend of learning features to deliver "...the right content in the right format to the right people at the right time." [10, p.139].

For students, online learning could be challenging if the delivered teaching content has not been created keeping them in mind. A well-designed learning design can help learners engage and interact well with the learning materials to acquire meaningful knowledge. Over the years numerous models, standards and criteria have been developed to evaluate the quality and effectiveness of online education, which includes both online teaching and learning components [6]. An effective learning design encourages learner's interactions with the materials as well as with the peers and instructors [11]. By using the latest learning technologies, the practitioners can incorporate collaborations, discussion and feedbacks in their design to improve these interactions. In fact, designs which create potential for these interactions can have a significant effect on students' "deep and meaningful formal learning" [12, p.4].

1.1 Learning design for Software Engineering

Software Engineering teaching draws from various teaching pedagogies to prepare students for their future. The focus of teaching Software Engineering has been mainly process oriented with the aim to develop problem-solving skills [13] and providing them authentic assessments to prepare them for real world projects [14]. Due to the nature of discipline, computer science students require hand-on practice to transform their knowledge to skills. For any instructional design to have significant impact on the learning outcomes of the students enrolled in computer science program, it has to incorporate strategies that are effective and supportive student learning. Learning programming can be considered challenging by many students [15]. Low problem-solving skills is an important factor that leads to frustration among students enrolled in programming courses [16]. It can be improved by creating an environment supportive of student learning. By understanding the students' learning styles, creating programming patterns and building upon them can significantly improve the programming skills [17]. Hazzan et al [18] have described the problems in teaching abstraction in computer science and the gaps in actual programming and thinking about problem solving. Pedagogical studies indicate that the use of collaborative learning strategies is a significant motivator for increased student performance in programming [19]. It is suggested to use active learning methodology to address these heuristics.

Future-ready students need to have multiple areas of expertise or at least appreciate how a range of skills fit together. More and more students are facing the prospect of finding employment at the end of their studies in industries or job roles that do not yet exist [20]. In a rapidly changing economy, the subject content in CS subjects should align in a way that gets students ready for a world which will need professionals with ability to communicate effectively and as well as to collaborate across different backgrounds and experiences. With the expectation of industry to have prospective employees not only technically sound, but also having transferable skills like communication, collaboration and time-management, it's important to provide the students various opportunities that can help in developing both these facets of learning.

The above issues can be addressed by creating a systematic model that can guide an effective learning

design, though the process can be very time consuming [21]. Learning designs are guided by precious student data that educators sieve through to understand how student learning has been shaped. The effectiveness of classroom practices is examined, and strategies are devised to improve delivery the in the next round of teaching. A well-designed online course can take six to nine months to develop [6]. The urgency to shift to online teaching due to the pandemic does not allow us that luxury anymore. Educators and learning designers need to come up with learning model which is time-effective, and which assists the faculty in delivering an enriching learning experience to the students. It should incorporate within it a range of digital tools and resources, use of which is guided by pedagogical awareness. The model also needs to include elements that can evaluate teaching effectiveness and the learning outcomes.

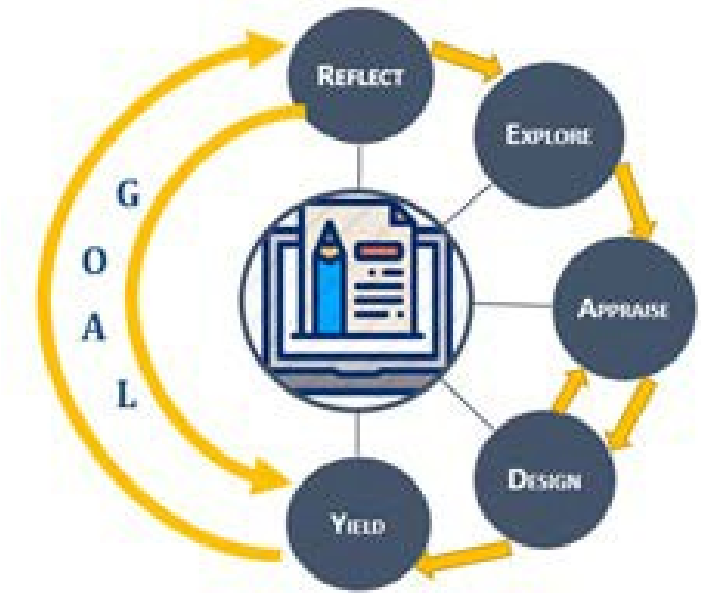

Figure 1: The G-READY Model

2. The G-READY Model

This model draws inspiration from the Greedy strategy in algorithms [22] that works on the principle of finding local optimum solution. It may or may not always deliver a best solution but can help mitigate the effect of situational factors that are beyond our control like unprecedented circumstances, which need urgent actions in minimum possible time. The proposed G-READY model aims to optimize student-learning experience by choosing whatever learning solution is readily available yet at the same time is the best fit for the students. Time being of prime essence in creating best possible learning experience in the uncertain times, the model aims to provide an alternative to the traditionally followed instructional models, which would need longer periods to complete the iterations. Unlike the traditionally used models, this model encourages the course designers to incorporate surveys and checks in the first iteration itself, making it possible for the educators to shift and switch modes/ assessments/activities as per the changing situations. Table 1 summarizes the suggested action points and resources for each of the phases described in the model.

Table 1

G-READY model- Suggested action points and resources

GOAL		
Define the purpose of the instructional design	Guiding Questions	
	1. What are the course learning outcomes? 2. What are the subject learning outcomes? 3. Is the learning design helping in transition from knowledge to skills? 4. What are the focused future skills needed in the work ready graduates?	
	Resources	
	Subject outline, Course Outline, Market skill requirements	
REFLECT		
Contemplate the ways in which subject design will help meet the subject goals.	Guiding Questions	
	5. Who are my students? 6. How successful was the earlier iteration in meeting student learning goals? 7. What content can fill in the identified knowledge gaps? 8. What situational/ environmental factors that affect the subject delivery? 9. What is the duration of the study period?	
	Resources	
	Student Feedback from last delivery/ iteration, LMS Analytic Reports, Peer Feedback, School Policies	
EXPLORE		
Scout for resources that will help deliver the goals efficiently.	Guiding Questions	
	1. What tools and learning resources are available for this cohort/subject? 2. Will this tool be a value addition to my classroom? 3. Are they from an open educational resource? 4. Do the tools align with my teaching philosophy?	
	Resources	
	Screencast and Lecture Recording	**Live Lecture**
	Audacity, collaborate ultra, Mediasite, Panapto, Loom	Collaborate ultra, Zoom, Google Meet, Microsoft Teams
	Interactive Quiz tools	**Online Whiteboard**
	Kahoot, Mentimeter, Socrative, H5P (Video quiz)	Twiddla, Miro
	Communication & Collaboration	**Peer Assessment tools**
	Announcement, Slack, Discord, Discussion forums, Trello, Padlet	Kritik, CATME, Peergrade
APPRAISE		
Evaluate and shortlist the tools that optimize student learning and performance	Guiding Questions	
	1. Is the delivery mode online or f2f or blended? 2. Do the shortlisted activities map well with the 'Goal' and the 'Reflect' phase? 3. Is there support for logistic/ monetary arrangements for chose tools? 4. Are there any alternatives available for the selected tool on the LMS? 5. How long will it take to set up and embed the selected resources in the LMS?	
DESIGN		
Organize a student centric, easy to navigate layout for the subject content and tools	Guiding Questions	
	1. Is flow and structure of the learning modules student centric? 2. Does the design include a range of learning tools and activities? 3. Have I evaluated the design from user's perspective? 4. Does the design include surveys and polls to get student feedback regularly? 5. Have the timelines for content delivery and assessment been set up? 6. Does subject design support building of student community?	
YIELD		
Knowledge acquisition and student experience	Guiding Questions	
	1. How did the student respond on the student satisfaction survey? 2. How did the cohort perform on the subject assessments? 3. How did the students engage with the subject design? 4. How did learning design impact the learner?	
	Resources	
	Pulse surveys, Polls, Assessment reports, learning analytics data, qualitative feedback, peer feedback	

2.1 The Goal Phase

The G-READY model emphasis the role of goal is the pivot around which the whole instructions deign balances. The first question we need to ask at this stage is “What is the purpose of this learning design?” Learning is most effective when it is guided by clear goals and expectations. In other words, goal guides the development of curriculum, activities and assessments as to ensure that the students achieve the desired learnings. Inspired from the ‘backward design process,’ popularized by Wiggins and McTighe [23], the process starts with a vision of the desired results. Backward design is beneficial to instructors because it encourages intentionality during the subject design process. Clarity on outcomes can give educators a focus and direction to develop a cohesive design content that will help meet the learning goals. For some educators the goals can be course-learning outcomes, for others it can be the subject learning outcomes. According to Wiggins and McTighe [23], having an explicit goal is like being purposeful as opposed to being purposeless. Clearly defined goals can lead to improved subject design and an effective and efficient study program [24]. Once the learning goals or desired outcomes have been identified, instructors can curate teaching and learning tools, develop assessments and design the subject around the established learning outcomes. Each of the chosen task or piece of instruction will have a specific purpose that is optimized student learning experience.

2.2 The Reflect Phase

In the second phase, information on the students, learning environment, nature of the subject, level of the subject, challenges that students or the teachers might face, the accessibility to the resources is gathered and reflected upon. The understanding of these elements will guide how the existing content and delivery methods must be modified, revised or changed to meet the subject goals [25]. In educational design research, reflection is an active process that allows the practitioner to connect the theory with the research and consciously examine and evaluate the reasons for making a choice [26].

2.3 The Explore Phase

In this stage the faculty becomes a curator overseeing the collection of subject tools and resources. This phase involves exploration of teaching tools that will deliver the initially established learning goals and satisfy the expectations of the reflection phase. Teaching is not just about engaging the students. The educators must ensure that the students have the relevant and appropriate resources to support their understanding. In other words, the educators should look for possibilities and explore the existing resource repositories in their quest for the most relevant and student supportive learning tools.

Over the past decades, students and their expectations have changed which could be due to multitude of factors including a technology rich upbringing. They appear to have “different” needs, goals, and learning preferences [27]. As they want to be challenged to reach their own conclusions and find their own results, the learning activities must include – “Interaction, Exploration, Relevancy, Multimedia and Instruction” [28, pp 5.7-5.9]. To meet these student expectations the educators can access the online resources, the resources available on the LMS, attend workshops to learn more about the available learning technologies and brainstorm with colleagues to develop a resource bank. A vast range of educational resource offerings are available on the internet too [29].

While exploring for the relevant tools/ activities, the educators should at all times guided by learning Goals. Since the G-READY model puts value on time efficiency, the educators should not spend too many hours collecting and organizing the resource bank. To help the educators access range of meaningful

tools and resources, Table 1 gives curated resource bank of activities/tools that can be used by the faculty in their classroom- real or virtual. The bank aims to bring a degree of efficiency when conducting such a search, as we understand how the time pressed staff sometimes might not be able to search far and wide for effective teaching resources.

Software engineering encompasses multiple phases from understanding of requirements to deploying and maintaining the systems. There are multiple tools available in the market for managing various processes of Software Engineering both for desktop downloads and for online collaborative set up. Due to sudden shift to a fully online teaching environment educators have to rely on online collaborative tools more than ever and appreciate their merits. Since, teaching of many Software Engineering concepts requires hands-on exercises, it is important to explore online learning, practice and development tools that can replicate face to face learning as closely as possible. Table 2 shows some of the teaching and industry specific tools that can help in providing an active learning environment with collaborative opportunities for student projects and practice which are an intrinsic part of any Software Engineering course.

Table 2

Online Teaching and Practice tools for Software Engineering

Software Engineering Teaching Tools	
Requirements and Modeling	Brainstorming: IdeaBoardz, Google Docs , Coggle, MindMeister Sketching: Sketchboard.io,sketch.io UML Modeling: draw.io,Genmymodel, Cacoo, visualparadigm
Teaching Coding	Online IDE: Repl.it, W3resource, CodingBat Visualization: Visualgo.net, Jeliot, Jive Assignment Ideas: Nifty
Collaborative Development	Komodo Edit, Cloud9, Colaboratory, Codepen, CodeLobster, Gitlab
Version Control	Github, Bitbucket
Design Thinking	Mural, Miro, MakemyPersona, Marvel, POP, AdobeXD, Stormboard, PingPong, Invision
Project Management	Trello, Github projects, Clickup, Google Code
Communication	Slack, Discord

2.4 The Appraise Phase

By purposely leveraging multiple learning pedagogies, a teacher can help learners become engaged, achieve mastery and knowledge [30]. As process of learning plays a significant role in what students learn [30][31], in this phase the faculty will evaluate the current teaching pedagogies for the subject and select the tools/ learning activities , curated during the Explore phase, as potential offerings to be included in the subject design in the next phase. Using effective learning strategies in classrooms can engage students better and engaged students are good learners [35]. Student engagement has been known to increases student satisfaction, enhance student motivation to learn, improves student performance and reduce the sense of isolation [36][37]. Table 3 is a guide to some learning methods and strategies and the corresponding activities as well as expected outcomes which can help educators make a decision on what to include for their weekly sessions.

Table 3

Outcomes associated with various classroom strategies

Methods/ strategies	Activities	Outcomes
Collaboration	Pair/buddy/ mob programming, Group projects, jigsaw collaborative method, peer feedbacks	Interactions with peers while working on a collaborative task enhances critical thinking [52], increases academic and social abilities [32], creates positive community feelings among students from diverse backgrounds and fosters socioemotional skills beneficial for overall functioning in today's environment [33][34][42].
Student engagement	Interactive multimedia exercises, Using social media, live quizzes using mobile apps, Quizzes built up in recorded lectures, Live discussion boards	Student engagement has been known to increases student satisfaction, enhance student motivation to learn, improves student performance and reduce the sense of isolation [37] [38].
Critical thinking	Open-ended questions, reflection exercises, Vignettes and case studies, problem –solving exercises (convergent and divergent),Online discussion, Questioning assumptions, peer assessment , brain teasers	Critical thinking can help students see e more solution opportunities. It also allows the students to effectively identify, analyze, and evaluate subject content or their skills [48].
Active learning strategies	Case studies, Digital labs and Simulations, Classroom response system (CRS), Role playing, Group discussion, Direct paraphrasing, E-textbooks	Active learning [35], [38] can promote student-teacher interaction [39] and enhance student engagement.
Formative assessments	Exit tickets, Self-test tools, Student created videos, Discussion forums, Peer review , mini-quizzes	Contributes to student engagement and learning by providing timely feedback to the student about his/her performance [40] [41][43] [44] [45] [46] [47].

2.5 The Design Phase

In the Design phase the role of instructor, assessment instruments, subject content, exercises and media selection are aligned to deliver a course, which addresses the goals and expectations established for enhanced student-learning experience. This phase is very significant since the actual delivery of the subject is kick started in this phase once the subject has been organized in the LMS. As can be seen in the Figure 1, the educators can move back and forth between the Appraise and the Design phase when including, discarding or reviewing the shortlisted tools if they do not flow well with the subject design or are not supportive of positive learning experience for the students or are not aligned with the initially set learning goals.

Subject delivery can be offered in a fully online or blended mode, wherein the content is delivered in the form of lectures and tutorials in a synchronous or asynchronous manner. When planning for redesign for CS subjects, a learner-centered approach is recommended, giving extensive attention to the needs, interest and skills of the students. This approach allows students to participate more fully in the arrangement of their own learning experiences [49]. By highlighting learner-centered approach, educators can make the learning journey enjoyable, engaging, relevant, and informative [50]. It also allows faculty to consider student engagement, learning, and assessment more intentionally [51]. The

selection of the tools and the subject content will then be such that it fits in well with the subject's instructional, visual and technical design strategy. Figure 2 offers an overview of building blocks for a robust subject design. The selection of the tools and the subject content can be made in a way that it fits in well with the subject's instructional, visual and technical design strategy.

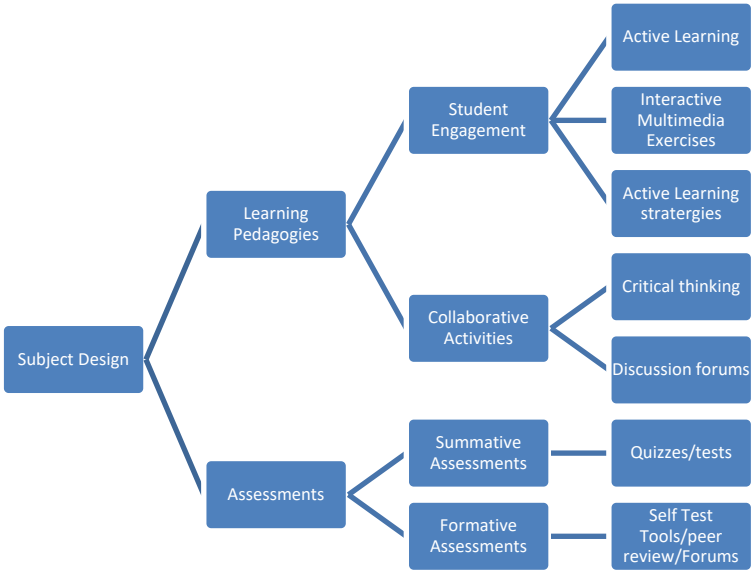

Figure 2: Building Blocks of a Learner Centered Design

2.6 The Yield Phase

The Yield phase includes the outcomes of the learning design. The student feedback gathered from the pulse surveys, teaching team feedback and Analytics from the LMS is examined to check for regarding what, how, why, when of the things that were accomplished (or not accomplished). This feedback allows the faculty to gain insights into student engagement with course concepts and the classroom/online activities that either facilitated or failed to facilitate desired levels of engagement [51]. The subject's formative or summative assessment results are evaluated to check for student learning. The assessment questions should be changed frequently, timed tasks, open ended/ critical thinking questions if possible. In group projects, have identifiable elements to ensure equity within the partnership. For example, communication monitoring through slack channels, version control and commit monitoring using Github or similar software.

By analyzing the feedbacks, educators can align their teaching with the Goal and go on to the reflect phase to introspect regarding what changes, if any, to be incorporated in the learning design so that the overall subject design is supportive of enhanced student learning experience.

3. Discussion and Conclusion

Software engineering education has evidently been changing rapidly due to new technologies and development paradigms. This paper proposes G-READY model which is a time-efficient and quick iterative learning design model that is student centric and supports educators. Borrowing from greedy strategy of algorithm analysis, it aims to optimize within constraints, teacher supportive yet learner focused content delivery. This model encourages a teacher to be a reflective practitioner who constantly evaluates the delivery and outcomes against the conscious reflections while mapping it with the goals. Teaching Software Engineering requires hands-on activities, with close supervision of projects,

collaboration between team members, multiple roles requiring regular feedbacks. It recommends that teachers explore the readily available materials at hand or access the curated sources to design and deliver learning design in the shortest possible time. For switching to an online set up, online teaching tools/ strategies and software project management tools have been suggested to make the transition easier. Besides addressing the purpose of various phases, the model supports time- efficiency as it provides a template of guiding questions and set of resources that can be used by the educators to suit their subject requirements. While the G-READY model was created primarily for teaching a software engineering course, but it is very flexible and can be adapted for use in any discipline. The proposed model addresses the gap in the existing learning design models that require longer planning and multiple iterations. The model is pivoted by the 'Goal' of the subject design and supports quick iterations which can be as short as a week.

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