Abstract: A number of researchers and educators have proposed educational methods over the years designed to improve our focus on students, their quality of learning, and experiences through academic and personal development. With a concern for moving forward, some of the more classical methods have been abandoned for the sake of progress, technology, and complex teaching pedagogies. We argue that in so doing, some of the basic core principles of learning have been lost, while students have been boxed into specific learning styles. Teachers also have been forgotten in their necessary role as mentors, and how fundamental they are in their capacity to shape intrinsic motivation to learn by teaching question-asking abilities and foster curious learners, especially in higher education. We here discussed and modified the theoretical model of learning (the Generated Question Learning Model—“GQLM”), prompted by teachers, whose role, we recommend, is to understand and practice the fundamental use of question-asking and critical thinking skills in learning. This article suggests that instructors engage the learners’ curiosity into essential cognitive behaviors with which all forms of learning can become possible and learners become well rounded. Teachers in traditional teaching methods transmit skills, while in active learning methods they promote learning and inquiry. This model juxtaposes the two styles of approaches through sensory stimuli (texts, demo, web-application, question-asking).

Subjects: Philosophy of Education; Theories of Learning; Teachers & Teacher Education; Curriculum Studies; Educational Psychology

Keyword: critical-thinking; learning styles; question asking; socratic; active learning

ABOUT THE AUTHORS

The Institute for Effective Thinking has for mission to develop research on educational challenges and the ideologies that become the foundation of curricula and influence policy and pedagogical strategies. We study strategies to encourage more inclusive and interactive teaching at the highschool and college level. The Institute’s members are educators sharing their ideas about their experience in the classroom. The authors strongly believe in the ability of students to be well rounded across skills if taught in a balanced and interactive manner.

PUBLIC INTEREST STATEMENT

The aim of this text is to improve the usability and impact of our model the GQLM. We broadened some aspects of the model by adding the component of the impact of language in the classroom. We’ve come to realize that teachers and students’ languages are so different that language is an integral part of learning. We now believe that the GQLM is a promising tool, bridging old and innovative instruction methods, allowing instructors to better embrace and serve their students. We also streamlined our major tenets embedded in a new instructors’ culture of guiding students to become authentic, curious inquirers, by the clever use and demonstration of question asking, and specific strategies that we have detailed further.
1. The generated question learning model
A number of articles seek to illustrate the positive results that stem from active-learning techniques such as for example: increasing student comprehension (Jensen, 1998; Krain & Lantis, 2006), enhancing student problem-solving skills (Bransford, Franks, Vye, & Sherwood, 1989; Lieux, 1996), increasing school retention rates (Hertel & Millis, 2002; Schacter, 1996; Silberman, 1996; Stice, 1987), or understanding abstract concepts (Pace, Bishel, Beck, Holquist, & Makowski, 1990; Smith & Boyer, 1996). Despite these claims, however, several recent studies note that most assertions are based on subjective impressions of the instructor or students (Powner & Allendoerfer, 2008; Shellman & Turan, 2006). Similarly, Raymond (2010) emphasizes a surprising lack of systematic empirical evidence backing up those claims.

Recent literature suggests that no single teaching technique is superior in teaching all types of contents and skills, and there exists a growing consensus that the techniques to be adopted should be selected based on the specific set of learning objectives (Gibson & Shaw, 2010). In their meta-analysis on what factors helps students learn best, Hattie, Biggs, and Purdie (1996) rank these factors across more than 40,000 studies (see Table 3 in Hattie et al., 1996). Out of this review, the number of studies that looked at questioning as a method of instruction and tool for better learning was surprisingly only 134. This highlights a large lack of studies that test the merits of this method for students’ successful learning. Dorn (1989) argues that active-learning techniques are more effective at teaching “critical thinking and problem-solving skills.” Active-learning methods seem particularly well suited to learning outcomes related to affective learning and the teaching of practical (or professional) skills; such as negotiation, mediation, bargaining, and consensus building (Gibson & Shaw, 2010), and for small classrooms, but how well suited is it in everyday classrooms where size and prior knowledge widely vary?

In this essay, we discussed and modified a recently published active-learning paradigm, the Generated Question Learning Model (GQLM) proposed by Crogman and Trebeau Crogman (2016). This model engages the learner at the most important stages of learning. In this model, students work intently on developing their question-asking skills, and critical thinking process, improving their problem-solving abilities. Most active-learning pedagogies are Constructivist-based learning models, in other words based on students actively creating meaning out of the material presented them, and being involved in their own learning. Crogman and Trebeau Crogman (2016) argue that the GQLM is actually foundational to Constructivist methods. By essence, it uses, maximizes, and enhances tools such as active-learning strategies and hands-on approaches such as Inquiry Based-Learning (IBL), or Problem-Based Learning (PBL), and Socratic interactivity. It strongly emphasizes questions formulation as applied to learning, and calls to focus on training educators to be experts in that seminal skills upon which all learning is based.

The GQLM encourages the practitioner to set-up instruction based on interplays between traditional and active learning methods for a balanced and flexible teaching. In this framework, the practitioner models and encourages question asking to help develop content knowledge through inquiry as well as problem-solving, reasoning, communication, and self-assessment skills. These generated questions also help to maintain students’ interest in the course material as they realize that they are learning the skills needed to be successful in their learning.

The goal of this essay is trifold, (1) to strengthen the model that Crogman and Trebeau Crogman (2016) proposed by identifying central features and discuss them in light of some preliminary results. We argue for some modifications to the model by considering lacking domains. (3) we provide some guidelines for planning redefined GQLM-based courses, suggest how to assess the updated model at all stages of instruction, and discuss the impact of the GQLM on student learning and motivation. We propose how to implement the GQLM in a wide range of classrooms, and expect a strong association between question asking and learning skill improvement in students. This result should be due to the GQLM’s using a multisensory pedagogy to increase students’ curiosity.
2. Rationale for a new learning model

Research shows that active learning models do not necessarily produce substantially better results than traditional teachings, even though they offer benefits that practitioners and students can glean from (Clark, 2006; Engel & Randall, 2009; Harasim, 1996; Johnson & Dasgupta, 2005; van Klaveren, 2011). Additionally, these active models, as designed, generally work best in small settings, and in large classes would require substantial manpower and resources. Furthermore, content is often sacrificed and simplified, and assessments quite subjective (Gibson & Shaw, 2010; Powner & Allendoerfer, 2008; Shellman & Turan, 2006). Edelson, Gordin, and Pea (1999) suggested five major challenges to face when implementing active learning models such as IBL, PBL, etc.: (1) Motivation, (2) Accessibility of investigation techniques, (3) Background knowledge, (4) Management of extended activities, and (5) The practical constraints of the learning context. It is our opinion that to date, not much has been done to show instructors how to address these factors in the classroom, in a systematic and cohesive manner. Critics also believe that these learning methods create cognitive stress and additional work overload for both instructors and students, and may result in potential misconceptions, making it difficult for instructors to detect problems.

Additionally, Graesser and Olde (2003) point out that, “questions are asked when individuals are confronted with obstacles to goals, anomalous events, contradictions, discrepancies, salient contrasts, obvious gaps in knowledge, expectation violations, and decisions that require discrimination among equally attractive alternatives.” Questions can be categorized by their production type (Otero & Graesser, 2001), and those depend on the sum of knowledge acquired given that, as Miyake and Norman (1979) said, “to ask a question, one must know enough to know what is not known.” Thus, another major challenge associated with active-learning models, and especially in most introductory science classes, is that the students’ exposure to prior knowledge must be a prerequisite for new content to be learned. Without some form of didactic teaching (Wood, 2010) students’ skills may be impeded. Thus, although some concepts can come from inquiry, others must be taught didactically (i.e. traditional teaching). Hence, the merits of such a hybrid method as the GQLM.

Dewey (1938) argues that in traditional teaching, teachers transmit skills as opposed to their role in active learning methods, in which they rather promote learning and inquiry. That said, despite the flaws detailed above, active-learning does have its place in upper division science or medicine programs where students already have the foundation to build on, and are normally in much smaller class sizes. This does not contradict the GQLM because, as mentioned earlier, this model is designed as a hybrid active learning model, facilitating the learning experience of a large variety of students in small and large classes from both upper and lower divisions. Wenning (2011a) argues that, “In an effort to adequately address the depth-versus-breath problem, it is appropriate to provide roughly equal amounts of instruction that are inquiry oriented and didactic. (...) Didactic approaches will help students address the broader content of science while inquiry approaches will help students better learn the processes of science.”

The larger the classes, the more opportunity there would be also to teach atypical students (learning disabilities, ESL, low SES) who need some degree of accommodation to gain access to learning. The GQLM possesses the attribute of multi-sensory learning pedagogies to awaken curiosity, which prompts student questions to facilitate learning for all levels (Rosenshine, Meister, & Chapman, 1996). It may then improve the teaching and learning experiences of these students who come in with more learning challenges than the average of the class. For example, Brock (1986) studied the effects of teaching English as a Second Language Students (ESL) to ask more and better-structured questions while learning a new language. The study showed an improvement in comprehension, in question asking frequency, and in interaction between the instructor and the students as they sought clarifications more easily. The benefit of asking questions was also tested within atypical populations with learning disabilities. Billingsley and Wildman (1988) suggest that teaching students with learning disabilities to generate their own questions helped them detect errors more easily and frequently inserted in texts they were given to analyze. Koege1, Camarata, and colleagues (Koegel, Camarata, Valdez-Menchaca, & Koege1, 1997), and Palmen, Didden, and Arts (2008) discovered that teaching how to ask questions to students with autism, whether severe or high functioning, gave them much better academic outcome opportunities.
The GQLM is a dependable model utilizing various types of components of active-learning models, which makes it an active learning model by essence. By active learning, we mean any activity that requires students to interact actively with the course material individually or in groups. For example, in physics classes, students often seem confused by Newton’s First Law. This is an important concept for students to learn, which has a major weight on their understanding of the material in the remainder of the course. In a 10 min long activity set-up to prevent potential confusion, students are asked to spend two minutes writing a response to the following question: “If we accept Newton’s Second Law which states that a force causes a body to accelerate, what statements can we make about the state of the body moving with constant velocity?” Next the students are instructed to turn to someone near them and discuss their statement with each other in three minutes; If they disagreed, they had to attempt to convince each other that their argument was correct. Finally, students are asked to write their statements on the board.

What happens in this five minutes exercise? Students are fully and actively engaged in their thinking, questioning, and cognitive manipulation of this important concept by questioning and challenging each other’s thinking as well. The instructor on the other hand, is able to assess student learning in real time, and clarify any misconception (See Mazur’s (1993) six-sequences active-learning strategies). Thus, active learning involves activities such as: class discussion, small group discussion, debate, posing questions to the class, think-pair-share activities, short written exercises and polling the class (Bonwell & Eison, 1991), that keep students engaged in the learning process.

Active models are declared to be student-centered with the instructors as facilitators. However, in the GQLM instructors are still central to the learning in that they ensure students are constantly inquiring and getting feedback. They do so through activities such as: group-work, role-playing discussions, cooperative learning, short written exercises, and being intentional in the instructional process. This mitigates a balance between teacher-centered vs. student-centered classrooms.

For example, the GQLM addresses each of the five active learning challenges mentioned above in its design. The classroom environment is set-up so that students can be easily motivated (Crogman, Trebeau Crogman, Warner, Mustafa, & Peters, 2015). Accessibility of investigation techniques, and background knowledge (discussed further in assessment) are also covered because the GQLM requires the instructor to have expertise in didactic teaching, which gives students access to investigative strategies and prior knowledge. Mayer (2004) also argues that guided discovery is more effective than self-discovery in helping students to learn and transfer information and skills. The GQLM like IBL, is designed to develop students’ engagement and manage their open ended-inquiry. As such, instructors must model what this looks like through their own management of extended activities. The practical constraints of the active learning context, in some sense, is limited by its content sacrifice and adaptation to new technology, but from the Finnish system’s successes, we see that this does not necessarily cripple the model (Crogman et al., 2015).

Again, as opposed to other active learning models, the GQLM combines didactic and active learning strategies, focusing on developing the students’ question asking ability by engaging them (Figure 1). For students, the key to successful learning with the GQLM is their curiosity. This model empirically (Crogman et al., 2015) demonstrated that if curiosity is fostered, then learners successfully thrive no matter what their initial strengths or weaknesses are. In this case, students rely less on prior knowledge to figure out solutions, even in introductory classes, because their question asking abilities can help them navigate novelty, and become effective problem solvers. Multi-sensory pedagogies move the lesson from didactic to active learning (Table 2 in preliminary results section). Crogman and Trebeau Crogman (2016) argue for pedagogies, which engage students’ visual, auditory and kinesthetic modalities simultaneously. A didactic pedagogy is the telling of facts or transmission of skills (Dewey, 1938), which is not experiential through the senses of the learner. The instructor can incorporate tools such as demonstrations (see Table 2), which are used as “wow” factors to strike at students’ curiosity. When pedagogies use questions or allow questions as a way to explore the concepts
through discussion, peer interaction etc., an active learning pedagogy takes place. Thus, multi-sensory pedagogies serve as a link between didactive and active learning pedagogies.

The ultimate goal of the GQLM is to transform learners into better question-askers by navigating between low and high order questions. It is different than IBL in the environment (Crogman et al., 2015) that it creates. IBL is atypical because it follows a basic four steps approach: 1/ Students develop questions that they are interested in, 2/ research the topic using time in class, 3/ present what they have learned, and 4/ reflect on what worked about the process and what did not. IBL works best if the learner has acquired a rich prior knowledge, and in small sized classrooms (Wood, 2010).

Additionally, there are numerous challenges faced by IBL for example are children' difficulties with conducting systematic scientific investigations (Krajcik et al., 1998; Schauble, Glaser, Duschl, Schulze, & John, 1995), and lack of prior experiences and motivation (Soloway, Guzdial, & Hay, 1994). Also, in the inquiry process, instructors are decentralized and act as facilitators, but this causes them to be shortsighted not knowing where students' weakness are (Bell, Urhahne, Schanze, & Ploetzner, 2010). Some researchers have argued that instructors in IBL seem to assume that students will hold the same assumptions and thinking processes as do professionals within that discipline (Bain, Donovan, & Bransford, 2005). However, the GQLM is not plagued by these artifacts by design. It uses sensory stimuli (texts, demo, web-application, questions) to activate students’ curiosity, which naturally drives inquiry. Numerous research studies have concluded that fostering curiosity by training students to ponder and ask, was successful in the case of both regular and atypical students. Because the GQLM is primarily drawing on learners’ curiosity, and advocates that curiosity is fundamental to learning because it directly engages learners’ question-asking processes, it sits at the foundation of all learning models (Crogman & Trebeau Crogman, 2016).

Commonly “questions asking” is promoted as a prominent feature of IBL, but these are not questions that typically result from the students themselves. GQLM, on the other hand, utilizes the Socratic method to enhance and develop students’ question. Thus, the questions-asking process is bi-directional. It does so because it methodically assesses concepts through questioning and feedback. This assumes that students can, in this multisensory experience, enjoy connecting old knowledge to the new, that thinking is born from question asking which branches onto more questions exponentially (Copeland, 2010). Socratic because it uses questions to create conceptual conflicts that cause students to examine their own belief to create new knowledge.
In this framework, instructors give demos or describe situations by which they can model question asking or probe students’ questions by: (1) proposing a question to ponder, and carrying out the inquiry in the presence of the students, (2) asking students to come up with their own question and carry out the inquiry, (3) asking questions directly or through technologies to probe students’ misconceptions or creating discussions that in turn draw out students’ new questions. In this context, like IBL, the instructor helps students to understand how to generate their own content-related questions but unlike it, the instructors give thorough instructions and models efficient thinking.

In upper division settings, medicine, or humanities the instructor in the GQLM acts purely as a facilitator or tutor since the model is designed for the instructor to utilize other active learning pedagogies (Figure 2). Thus, in using the GQLM, the practitioner must be quite fluid, and able to adapt to their learners’ needs and challenges. Ultimately, the GQLM brings instructors back from the sidelines, because as Hattie (2008) argues, effective instruction exists only with proper feedback. Arnold (2011) reports: “Hattie convincingly argues that the effectiveness of teaching increases when teachers act as activator instead of as facilitator, a view which I find refreshing in a time when teaching approaches such as problem-based learning have the effect of sidelining the instructor”. Thus, the GQLM is versatile, moving flexibly between Didactive and Active teaching. Through these pedagogies, it effectively uses both qualitative and quantitative assessment tools.

Figure 2. Generated question learning model in the classroom.
In this section, we made a case for the use of the GQLM as a better alternative to existing teaching practice. However, we have taken notice that, the prior model by Crogman and Trebeau Crogman (2016) fails to account for an essential aspect of the atypical student by just considering question asking in their case, as a fundamental tool for learning. However, often, these students are neglected as a result of the lack of sensitivity to their language and culture, which should be intentionally incorporated in their learning. We propose that language is essential in helping and improving the atypical students acquisition of question-asking skills. Work must be done to allow these skills to be transferred to other cognitive domains, which will increase their vocabulary, and communication skills with people in their environment. In support, Newmann (1992) makes an interesting case about being intentional about language in instruction. He says that, when students are forced to embrace and manipulate a language that is not theirs in their learning, their construction of solutions in learning is negatively impacted, which also has an effect on their relationships with others around them and how they perceive those interactions. He posits that instructors should focus on facilitating the unique language or discourse of students to help them develop better personal discourse/debate and solution seeking in their learning experience.

3. Features of the GQLM

A point worth noting is the amount of studies (see the substantial review of more than 40,000 studies gathered by Hattie et al., 1996) which highlight the benefits of some teaching and learning strategies which are implemented in the GQLM: The importance of instructors’ teaching style (5,009 studies, effect size 0.44), students’ disposition to learn (93 studies, effect size 0.61) which is a radically small number, yet capital to the understanding of how to engage students better. The review also mentioned ability grouping (3,385 studies, effect size 0.18), and direct instruction (253 studies, effect size 0.82). Note that all these studies have rarely combined these important elements together into a comprehensive teaching and learning model, but have studied each of these learning methods individually and found positive results. The GQLM combines what works best, and functions as learning feedback loop in the classroom. It specifies the underpinnings of the skill of learning (Crogman & Trebeau Crogman, 2016), and focuses on showing how to be engaging with the learner’s sensory and cognitive processes through which learners use question-asking to clarify their thinking. Instructors’ pedagogies offer students the tools necessary to become adequate “inquirers” making them receptive to, and curious about the material to be learned.

Figure 1 breaks down how the learner’s sensory engages with the environment through which the practitioner actively shapes their pedagogy, and students develop questioning and critical thinking skills. It illustrates how pedagogy informs the environment, and generated questions showing that instructors use pedagogy to change the environment, and keep the learners engaged, or asks questions to bring concepts to life. The learners’ curiosity is awakened due to interactions between stimuli in the environment and their senses, after which learners, generate questions and begin the inquiry process. This has the potential to influence their cognitive, social, and personal development, the assessment of their work, and their reception of appropriate feedback.

3.1. Instructor’s role

In the GQLM the instructors’ role in the classroom is as follows (Crogman & Trebeau Crogman, 2016; Crogman et al., 2015; Ramsden, 2003): (1) Teaching as telling or transmission of knowledge (didactic), (2) Teaching as organizing student activity and fostering active learning (IBL or PBL etc.) and, (3) Teaching as making understanding and critical thinking possible through question asking practice. The instructor plays a critical role in helping students become self-directed learners, and must create a classroom environment in which students “receive systematic instruction in conceptual, strategic, and reflective reasoning in the context of a discipline that will ultimately make them more successful in later investigations” (Gallagher, 1997, p. 337).

In addition to emphasizing learning through question-asking, like PBL, the GQLM requires students to be metacognitively aware (Crogman & Trebeau Crogman, 2016). They must be conscious of prior knowledge, or lack thereof, about the problem, and develop different levels of questions to ask about
the information they need to know to solve the problem. For this reason, the instructor must become a tutor or “cognitive coach,” modeling inquiry strategies, guiding exploration, and helping students clarify and pursue their questions through different means and activities (Arámbula-Greenfield, 1996). We emphasize that practitioners must be versed in a variety of active learning, socratic, and didactic strategies to be effective (Figures 1 and 2).

For example, the GQLM uses active and interactive elements such as group-work, monitored and facilitated by instructors, which has been demonstrated, as an essential aspect of any active learning environment (Hertz-Lazarowitz & Miller, 1992; Jaques, 1991; Johnson, 1991; Kimber, 1996; LeBrun & Johnstone, 1994; Leming, 1985; McKeachie, 1987; Nastasi & Clements, 1991; Slavin, 1991; Sharan, 1990; Sharan & Shachar, 1988). First it helps develop learning communities where students feel comfortable developing new ideas and raising questions about the material (Allen, Duch, & Groh, 1996). Secondly it enhances communication skills and students’ ability to manage group dynamics.

Cohen (1994) argues that well-designed, open-ended problems requiring the input and skills of all group members, also are essential to positive group-work experiences. Consider also practices such as the idea behind the Flip Classroom (Bishop & Verleger, 2013). In that case students need to be exposed to lectures and some content to be reviewed before class. Practitioners can make use of and navigate between these different techniques, along with activities such as Just In Time-Learning (JTL—students must list three things they’ve learned, and write a question they still have on course content), for students to reflect on the material outside of class, and ask questions during class time. In this format, the practitioner interactively involves the whole class through discussion, activities, demos or case studies, as in the Flip, along with shorter but structured lecturing.

The better trained the GQLM instructors are in being flexible with teaching techniques, the better prepared they will be with supporting students with learning deficit or disabilities. How must they be approaching these students? The main objective is being able to identify them and tailor instruction to reach them. Instructors can use their GQLM tools such as Concept Inventories (CI) to assess students’ base knowledge, which indicates what group of students will struggle in the class and with what topics. Thus, the instructor is able to manipulate instruction to meet student specific needs. A note of caution, the GQLM as it is, can address some learning disabilities, however, others may require additional support in collaboration with campus services such as the disabilities office.

### 3.2. Questions pedagogy

Questions are at the heart of any complex task that we perform, and unfortunately learners are often ill-prepared in question-asking skills, and their educators in fostering that skill. A large number of active learning pedagogies do little to improve student question asking potential. Black and William (1998) remark that, when breaking down questions quality in a set of observed instructors, their utterances were more often crystallized at the recall level rather than based on fostering higher order thinking skills, even after being trained in that domain. So too, a number of educational studies reported the low incidence of students’ questions in class, or how those questions most often remain superficial (Dillon, 1988a; Graesser & Person, 1994; van der Meij, 1988). This could be an artifact of the lack of training in instructors to promote that in their teaching pedagogy. Thus, we believe that more needs to be done to get learners involved. However, as far as superficial questions are concerned, the issue is not relevant as, we believe, it is the function of the educational practitioner to model how to ask high-level questioning until students are able to emulate it.

In the interactive GQLM’s framework, the practitioner must model how students’ question asking must be developed to enrich the learning experience (Figure 3). McComas (2004) suggests that “the first step in asking better questions is to identify the types of questions we are currently asking, why we are asking them, and finally, what techniques can we utilize to improve the questioning that occurs in our classrooms.”
Questions help instructors assess the level of their students' understanding in real time (or misunderstanding), and simultaneously use that to engage and encourage their ongoing participation (McComas, 2004). Research actually showed that students' own generated questions produced better results than direct questions from instructors (Black & William, 1998; Koch & Shulamith, 1991), which is the ultimate goal of the instructor using GQLM.

Further, questions are used to allow students to express their thoughts and hear explanations offered by their peers (Brualdi, 1998a, 1998b). Learners can also express themselves through the JTL which allows even shy learners to engage in the question asking process. The way in which practitioners engage students’ question asking will determine these students’ transition from JTL to be more vocal participants. Figure 3 shows the practitioner using question asking to open the students’ memory and using IBL pedagogy to promote exploration in students now using their higher cognitive processes. Thus, GQLM is helping to mature the learner question asking process.

Figure 3 illustrates two types of questions: a low level cognitive question type, which only requires recall of facts; and a higher level cognitive question type, which forces students to apply knowledge. These two types of questions can be broken up into convergent and divergent categories (Figure 3). Instructors should move between these types to polish students’ question-asking skills. Appendix A details concepts found in McComas (2004), which illustrate these question-asking processes and question type levels recommended to develop students' depth of critical question asking processes.

Every problem can be decomposed into a set of tasks (Figure 4), and every task can be divided into a question followed by inquiry to address it. We are making a difference between question asking and inquiry since a number of educators see them as one and the same. Inquiry is really an information gathering stage (researching resources, studying, crafting an experiment, observing, or interviewing) that arises due to the question that is being asked. Instructors should deconstruct tasks into a set of questions, followed by inquiry to provide the learner with answers (Figure 4). That is,
questions have the ability to push the learner to explore. We represent this concept through the following equations:

\[
\text{task} + \text{inquiry} = \text{answer}
\]

Every question is better refined through feedback and inquiry. The equation below and Figure 4 illustrate that feedback allows the task to be refined (as represented by the minus sign).
task = \sum_{i=1}^{n} (\text{question asked},_i - \text{feedback},_i)

It is true that questions are also part of the inquiry process in the sense that they are recast to refine the line of query, or go down a new path that the original question did not or could not anticipate. Further, questions are redefined throughout the learning process, to guide and refine inquiry. Thus, feedback comes from the learners' reflection on the task or as they engage in inquiry, which endows them with better clarity to find the solution. As shown in Figure 4, the various answers contribute to the overall solution of the problem.

Figure 5 shows a typical pedagogical pathway between the instructor's strategy and the students' problem-solving outcome. There must be an exchange between the instructor and student, which takes place at the low-level question stage, and helps students better engage in the inquiry processes (this is illustrated by the two-way arrow in Figure 5). As suggested, the teacher must utilize a multisensory stimuli approach as platform in which students can find interest and build new inquiries.

These platforms are crucial opportunities for instructors to systematically engage the majority of students' learning skills (visual, verbal, ...). This practice allows students to always delve further into, and develop all of their abilities to enrich their capacity to build stronger inquiry skills (see Figure 1). Students use these senses to interact with stimuli manifested in various learning modalities and help access solutions to problems from diverse angles (Crogman & Trebeau Crogman, 2016).

3.3. Environment

The GQLM posits that a successful active environment requires interplay between Socratic-like teaching, active learning tools, and didactic methods as shown in Figure 6 (see Crogman et al., 2015 for a description of the interplay between Didactive and Socratic teaching).

![Figure 5. Problem-solving teaching through question modeling.](image-url)
The Socratic approach to learning uses questions to examine the values, principles, and beliefs of the learner and may create productive discomfort (Ross, 2003). In other words, it creates conceptual conflicts, which engages the learner’s curiosity. The GQLM is designed to provide a comfortable environment where students feel safe, and when the subject matter is discomforting, they learn to feel confident enough to explore and formulate new questions and learn (Crogman et al., 2015).

The model starts with an environment intentionally set up for obtaining a desired outcome from students. It is framed by the pedagogy of the instructor, his/her intentionality in facilitating comfortability and connectedness in the classroom, and his/her preparation (Crogman et al., 2015). Intentionality from instructors fosters the optimal conditions for giving to every student an equal start in a classroom where they come unequally equipped, and may have different learning backgrounds to begin with. Comfortability allows students to feel that they are safe to interact, ask, comment, and be an integral part of the interactive classroom. Connectedness affords students the understanding that they matter, are cared for, and that they can find in their instructor someone they can relate to. Preparedness gives the students the opportunity to grow in a guided environment where the material is accessible, interesting, where transitions are smooth, and material organized and relevant. In such an environment, even atypical students strive, emerged in a learning space where instructors believe in the success of all. See in the next sections some of the GQLM tools, which make the learning environment accessible to all such as CIs and regular learning checks to help instructors keep up with the students’ progress.

3.4. Senses
The GQLM takes into account the senses of the students in their integrality. Crogman and Trebeau Crogman (2016) argued that students have learning modalities that encompass all the senses instead of having one dominant type of learning style. A survey was given to 80 students, in which they chose the particular learner they perceived themselves to be then they took a test matching them to the learning styles they selected in the survey. The results from the test showed that no students were matched to any one learning styles. Their answers encompassed all categories of learning styles, despite their prior choice, without gravitating toward what they knew or had declared themselves to be. Crogman and Trebeau Crogman (2016) contend that all students are equally capable to
learn from auditory, kinesthetic, verbal, or visual senses or the like. They argue that, for example, a student given a song’s lyrics can only learn the words (visual) and know the meaning of the song (verbal), but there is no insight into the tune until they hear the melody (auditory). Hearing the song, and learning to sing along adds more dimensions (kinesthetic), and by seeing the song in a video (visual–auditory) for example, it becomes possible to make even further associations to remember the song (repeating and long-term memory storage). Thus, the GQLM posits that an environment must be tailored, and sensitively facilitate learning through the development of ALL learning modalities. This is best achieved by the instructors’ pedagogy. Using sensory stimuli, optimized student learning, in that they are drawn into sensory learning awakening their curiosity, driving a need for exploration and question asking. For example, in science, concepts are reinforced by laboratory exercises, which foster kinesthetic practice, and motivate to pursue discovery. Consequently, in GQLM, using the senses is central, with the goal of the instructor intentionally providing sensory learning opportunities for students to use and develop their various learning abilities (see Figure 2).

3.5. Language and comprehension

We modified Crogman et al.’s (2016) diagram (see Figure 1), taking into consideration that being mindful of language is a necessary and unavoidable requirement in instruction (Crogman, 2017). It is a factor weighing strongly in the act of learning, and shows that, when it is ignored (for both students and instructors in their own spheres), learning deficits ensue. Further, Crogman (2017) demonstrates the interplay between language and thinking in which again, language is central, and without which higher order thinking would not be possible. In Figure 1, language was incorporated at two levels: L-Language (Learners’ Language), and I-Language (Instructors’ Language). Language is an important skill for the learner because it streamlines and rationalizes thinking, and shapes questions.

Language, questions, and curiosity are partners in the learning process. The work of Berlyne (1960) and Malone (1980) shows that there are two types of curiosities: Perceptual, Epistemic (Berlyne), and Sensory, cognitive (Malone). Malones’ cognitive and Berlyne’s epistemic curiosities are equivalent. However, Crogman (2017) argues that there is indeed a base curiosity, divided into Perceptual and Sensory. The difference is that perceptual curiosity is the feedback of language on the sensory. It is in the perceptual curiosity that human curiosity begins to be distinguished from that of animals.

Consequently, L-Language influences perception, and as a result, is responsible for how the learners think and interact with the environment. Adequate language development leads to better comprehension which is the foundation for the learner to develop good question asking skills (Martin & Duke, 2011). When L-language is neglected learning deficits go unchecked, and can lead to false diagnoses (i.e. learning disability). For example, in African-American students, word choices and pronunciations are often misunderstood, and deemed inappropriate (Green, 1998, 2002). This causes large mislabeling and neglect of this group’s needs (Ford, 2010, 2013; Gardner & Hsin, 2008; Whiting, 2009).

Language impacts comprehension, which affects two major domains: understanding and reflection. Figure 1 shows two arrows from the comprehension domain, one to the thinking domain and the other to the curiosity domain to illustrate their important connection. Further, how the learner reacts to external language (I-language) is connected to their own language development. Therefore, I-language helps to shape pedagogies that are accessible to students, and allows them to relate to their instructor. Our understanding of Crogman (2017) argument is that L-Language distinguishes the pathway differences between curiosity in animal and humans. Learning success in consequence, may become more pronounced when there is a positive interaction between L-Language and I-Language. Further, when I-Language (pedagogies, peer interaction, instructor) accounts for the L-Language development, the environment becomes optimal for student learning.

It is important that practitioners be familiar with the storylines and language of their students, because it stems from culture, and impacts the classroom, with all its attached prejudices and
stereotypes (Crogman, 2017). This is one of the reasons for the GQLM’s practitioner centrality, and cultural sensitiveness necessity to connect to their learners. Being of a cultural minority with strong understanding of cultural biases, we have observed that, when an environment is created where L-language is accounted for in the pedagogy, learners become more attentive and motivated. As such, in a recent survey data, being intentional in the use of language for GQLM-based instruction, showed a strong association between students’ curiosity and the number and quality of questions asked. Also, better comprehension of the subject matter was observed since learners’ CI test data performances improved. Crogman (2017) proposed that, question asking may be the easiest and most effective way to improve learners’ academic performance, whether the learners have learning deficits, come from a poverty-stricken community, or are in a place where cultural barriers have hindered the academic development.

Language is foundational to all cognitive domains, subjects, and tasks. Constructive language interaction helps to develop strategies that provide the pathway for self-reflection and metacognitive thinking. Since the GQLM is a formative assessment (assessment procedures conducted by teachers during the learning process in order to modify teaching and learning activities to improve student attainment (Crooks, 2001)), model performed by both by the instructor and students, specific attention to language is paramount for further progress in learning. We detail this through the use of L-language and I-Language. That is question asking comes in the interaction between I- and L-Language via multisensory stimuli pedagogy. Learners are constantly engaged with their peers or instructors, which tends to help their self-reflection. Further, note that most language-based learning disabilities find their cause in neurological dysfunction or are the consequence of socio-economic difficulties (Newhall, 2012). Often times current instructional pedagogies have developed without this group in mind. Newhall (2012) argues that such individuals need specialized, explicit, and structured instruction. One that is multisensory, constant, and guided to support areas of challenge. This is what GQLM framework attempts to achieve for all students.

3.6. Perception

Students sitting in a class are processing centers whom senses are affected by the environment. Their thinking abilities in that context will matter for their learning. Crogman and Trebeau Crogman (2016) note that to obtain a desired stimulus response reaction, senses must be online. This is perception, and it must be alert and ready to work in the form of awakened thinking, attentive curiosity, and available knowledge (Figure 1—perception box). The way we perceive and interact with our environment is based on how we develop language. In other words, language is the fabric of perception; it formulates and constructs our perception. It is the signifier for all high-level systems of meaning such as scientific theories (Lemke, 1990; Martin, 1991), and is a resource in constructing meaning (Halliday, 1993).

As such, in Figure 1, if a change in the learner's environment is sensed, a response is evoked. Here, instructors are agents of change and disequilibrium, keeping that system alert for learning through the use of L-language. The environment-senses interactions keep the learners’ perception online (Figure 1) via L-Language. Shaw (2006) contends that we sense and interpret through thinking. Thus, the mere perception of the material presented, coupled with the environment in which students evolve, gives birth to simple thinking processing which can lead to two routes.

(1) Thinking may lead to raise questions, which, if met with available satisfactory knowledge will be answered and stored (stimuli encountered are checked against stored knowledge to see if the learner already experienced it). This is illustrated in Figure 1 by the arrow that goes from thinking to knowledge. Thus, knowledge must be comprehended for the learner to know whether what they are experiencing or perceiving is new or not. We modified Crogman and Trebeau Crogman (2016) model to reflect this fact. Now if stored knowledge falls short of providing a satisfying answer, curiosity is awakened by the questions generated (question mark). Otherwise, the path may end, perhaps by lack of interest (Stop).
(2) On the other hand, thinking and pondering may lead to increased curiosity if the available knowledge is insufficient (Loewenstein, 1994; Ram, 1991), or the stimuli unknown (Figure 1, arrow from thinking to curiosity with a question mark). In that case, the thinking process of students exposed to novelty in their environment will be confronted with a desire for search, and pursuit of discovery by generating question. Most questions may start basic but the experience they create is fed back to enrich the learner’s question asking skills and the level of the generated questions will be based on how well they comprehend the material at hand. One way to help that is using GQLM’s short lecture format (about ten minutes) when presenting a concept that students with lower attentional skills, for example, students with attention deficit disorders, for example, may not be lost in the process. Added to that, sensory learning tends to bring a wow factor that entices the learner’s curiosity into inquiry. If presented in short activities, these tend to keep the students engaged while targeting very specific learning outcomes.

A GQLM user must always keep these feedback loops in mind to preserve a positive perception of the class, and the content. Instructors should constantly assess what is known and unknown, playing off of what could potentially create questions to keep the students’ perception box alert throughout the teaching process (Black & Wiliam, 1998). This can potentially “heal” the lack of question behaviors we typically see in college classes for example.

3.7. Generated questions
At this level of the model, questions arise, and further thinking processes have to come online to solve newly found problems. There, the instructor has once more, the opportunity to enrich the environment using traditional and modern thinking-enhancing and question-asking strategies (Crogman et al., 2015), (Figure 1 – arrow from pedagogy to generated question). Instructors must also provide a stream of constructive feedback to guide learning through these thinking and questioning processes, which will in turn enhance the instructor’s pedagogy and the students’ now enriched perception. In the classroom, this comes through basic exploration such as laboratory, vignettes, polls, role play, challenges, videos of which students must guess the end, and apply the concepts, or other interactive techniques designed by the instructors. King (1990, 1991, 1992a, 1992b, 1994) found that training instructor in practices which prompted students to generate specific thought-provoking questions, and their attempt to answer them, is more effective than training in other study techniques.

For example, an instructor versed in Socratic strategies can bolster students’ inquiry behaviors by asking more targeted questions, and model that critical thinking process they now can emulate. Additionally, training students to ask more targeted questions of their peers help the quality of their discussion, which will in return enhance the students’ thinking, resulting in increased learning and better problem solving abilities (King, 1991). In Socrates’ Meno, the slave boy achieves a correct result through Socrates’ question asking approach. Socrates claims that he arrives at his conclusions because the question posed drew out the knowledge the boy already possessed. Although our premise is not that knowledge is innately possessed, but rather we are saying that questions can be used to draw out knowledge already gained to solve a problem, or questions can be used so that the most novice of learners can create new knowledge or experiences.

3.8. Exploration
The basics aspect of exploration is play. Today we understand that toddlers’ play helps their language development, which in turn impacts their play skills (Lyytinen, Poikkeus, & Laakso, 1997). In observing play behaviors, researchers suggested that children are developing the foundations for successful social, communication, motor, and academic skills. Toddlers begin to imitate the language and behavior of others and engage in make-believe play (McLean, Bailey, & Wolery, 1996), which increases their curiosity about the environment and understanding of how things are similar or different. From play children learn how to interact with their environment, discover their interests, and acquire cognitive, motor, speech, language, and social-emotional skills (Piaget & Cook, 1952). Thus, how well the learner handles the inquiry process will be based on how well their L-language has been developed and whether play was the foundational to their development.
From Figure 1, as the learner’s interest is heightened from the multisensory stimuli, their curiosity activates their question asking modality which now requires them to set out on their quest of exploratory behavior. When questions are generated in the mind, the learner sets out to correct the resulting conceptual conflicts. Thus, exploration requires the three pillars of IBL: experiment, observation, and analysis. This we have modified also from Crogman and Trebeau Crogman (2016) Figure 1. At this point, the learner plays with the concept and subdivides their original questions to come up with a solution or deeper understanding of the problem.

3.9. Pedagogy
The GQLM emphasizes interaction and question-asking behavior, which when merged with active learning and didactive practices, makes question asking central to learning (Crogman et al., 2015). One of the most important pillars of this model is the formatting and content of the pedagogy of the instructor. Such a factor can make or break a classroom. The instructor must keep in mind to be mindful of their I-Language to connect to the learner’s storyline. I-Language also influences peer interactions since this pedagogical language is now framed in the cultural norms familiar to the learners. Peer interaction helps to enrich exploration and serves as a check of L-Language question generation. As consequence, which content, strategies, tools, technologies or words are used, is fundamental to students learning. Therefore, even with a potential disadvantage, any student would benefit from an instructor’s intentional design, one appealing to all learning abilities, sense, and curiosity. The instructor’s pedagogy informs both the environment, and the generation of questions, making for an interactive thinking “hub” classroom where critical thinking is alive and learning happens.

Pedagogy must have multiple facets, which will not be addressed in its entirety here as it reaches beyond the scope of this paper. However, in the context of GQLM and question-asking, pedagogical tools must revolve around the following elements to serve students best: tools that intrigue, the questioning of prior knowledge, stepwise solutions to a question where steps must be figured out by students or modeled by instructors, constructive feedback, short term work, and work that requires several class sessions to complete, in group or alone. A class must also be set up as an interactive platform, with less lecturing and more exchanges, and students must feel that it is easy to ask, be answered to, and produce work. For example, with JTL as one form of question-asking technique, students write or post their questions on the course online using web-based technology such as Moodle, Canvas, or Blackboard, in an attempt to facilitate their access to knowledge through technology (Colbert, Olson, & Clough, 2007). JTL gives the instructor insight into learners’ learning progress for it acts as a formative assessment tool and brings the student L-Language to the instructor attention. JTL the same authors note, is an excellent tool for instructors to get a real-time sense of where the class is, and obtain a starting point for the next class’ instruction.

Crogman et al. (2015) tested JTL in college classes and found for example that more than 60% of students found the method very helpful to them being active in class when their questions were discussed. Other useful tools:

• Class and web-based demos (which students pay more attention to given that their questions are used within instruction to improving teaching and learning Colbert et al. (2007).
• Free Response clickers tools. Shapiro and Gordon (2013) showed a 10% gain in performance after using clickers. Kushnir (2013) using EGG data showed an improvement of performance, attention span, and reported that 85% of students said enjoying that strategy, while 78% believed that it helped with their learning. Keough (2012) noted, in addition to the above that clickers use also resulted in high attendance, participation, satisfaction, feedback, and ease of use.
• Well and ill-structured problems (PBL), which optimized student learning, increased performance and understanding Fölmer, Barbosa, Soares, and Rocha (2009).

Crogman and colleagues (2015) also reported that more than 90% of students tested under the GQLM model reported that it was easier to engage in peer-to-peer work in this type of interactive
environment, which they claim was effective in their understanding of the subject matter. They also stated that one-on-one interactions with the instructor, who showed real interest in them helped with their connection to the professor and their classmates, and assured their success in the class.

### 3.10. Critical thinking

Each generated question can be elaborated, increased in complexity, or answered in a manner that will enhance learning. Instructors can use the questions asked to experiment, ask students to observe a phenomenon, or to analyze some aspects of the questions. This provides the feedback that sets critical thinking in motion. These strategies carefully understood and implemented by the instructor lead to promote critical thinking and higher order thinking skills from diverse angles (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956). There, the instructor can cater to all the senses through the answers given and the guided questioning (oral, visual through demonstrations and observations, practice through manipulations and experimentations etc.).

### 3.11. Experience

Experiences in the context of Figure 1, is the knowledge we create or apply from the interaction between the learners’ sensory and the environment. Crogman and Trebeau Crogman (2016) argue that, “from experiences, the critical thought process is influenced and new knowledge is created and stored in memory; it can also assist in the problem-solving effort of the learner (shown by the feedback arrow into the learner’s perception and critical thinking–Figure 1).”

In essence, experience is the formation of new knowledge through the interpretation of stimuli occurring between learning and the perception that senses afford. In other words, at the perception of a favorable (or otherwise unfavorable) environment, the senses are solicited and stimulated by materials presented. Curiosity is sparked and pushes to ask questions. Experience here informs each of the model’s stages, and feeds back into the perception, and the generation of questions.

### 3.12. Feedback

One observation that was not noted by Crogman and Trebeau Crogman (2016), which we inferred from their Figure 1, is that feedback deepens the learner’s thinking process, thus fostering cognitive curiosity. The latter in turn strengthens the learner’s critical thinking through reflection and exploration as new questions come with each feedback. At the first pass through Figure 1, the learner experiences surprise, their curiosity is withdrawn, and they may produce more low-level questions. With each new cycling through this loop, the learner’s language shifts and deepens, with higher order questions, to clarify their thinking about the problem, concepts or phenomena, and their curiosity moves from perceptual to cognitive.

Feedback in general allows for any model to undergo both formative and summative assessment. The feedback loop in Figure 1 allows formative assessment through the use of L-Language and I-Language. Students’ thinking is reformed through their interactions with peers and instructors (I-Language); L-Language is better developed through this interaction, which causes the learner to self-regulate their learning. Formative assessment allows a descriptive explicit feedback loop in student learning, and helps them increase their ease in learning and grasping of concepts (Friesen & Scott, 2013). Peer interaction also helps in the feedback loop to strengthen the thinking of the learner and as such, the critical thought process is enhanced. Wong and Jones (1982) taught students diagnosed with learning disabilities, through training, to “self-question” to improve their metacognitive skills and abilities to monitor their own learning. The training significantly improved the quality of the students’ questions, as well as their comprehension. Similarly, Reis, McGuire, and Neu (2000) studied successful college students with diagnosed learning disabilities. They found that, among the compensatory strategies these students developed, engaging in self-reflection and metacognitive thinking (for example, asking oneself a question and answering it), largely contributed to their success.
Good thinkers have been found to be also good questioners (King, 1991, 1995). This means the thinking and questioning must share a symbiotic relationship. But how do we become good thinkers? By encountering unknown multisensory stimuli which have the tendency to draw curiosity through which the learner, having no formal training, normally responds to by asking basic questions. This begins the journey of exploration, and here the learner reflects on, and asks further questions which cycle through a process as illustrated in Figure 1. This critical thinking is formulated through learners’ self-regulation and I-Language supported by the pedagogies and peer interactions as feedback loops. Again, King (1995) suggested that, “the level of thinking that occurs is influenced by the level of questions asked [...] however, when questions are thought-provoking, then critical thinking is more likely to occur.” Researchers have shown that, when students are asked to generate questions on their own, they usually pose factual rather than thought-provoking ones (Dillon, 1988b; Kerry, 1987; King, 1990). That said, in the GQLM, the interaction between I-Language and L-Language allows students and responders to go beyond the facts to activate their critical thinking process.

One problem for applying most modern teaching methodologies is the diversity of students’ backgrounds. Instructors are faced with challenges on how to shape pedagogies that reach all students. The GQLM offers a framework to accomplish this. Socrates Memo’s slave, in essence, presents to us the power of question-asking in the classroom, by transforming a hypothetically uneducated slave into a scholar by teaching him how to inquire. We think that by considering the L-Language of the learner, the instructor’s I-Language intentional use can overcome this diversity problem by starting with the very basic of questions about concepts and relating them to the diversity of experiences. This will reach into the intersections of the classroom. It is for this reason that the GQLM must impose on the language interaction between the learner and their instructors to reach into the cultural diversity in the classroom.

4. Class structure and format
As pointed out by Crogman and colleagues (2015), one-on-one peer interaction is the most productive way for a student to learn but such an approach is costly in larger classes. Active learning strategies in essence tries to mirror the effects of one-one interactions, and GQLM is designed to foster this feature more readily. Figure 2 summarizes the various components that are necessary to create the right classroom environment. To create an interactive classroom where learning thrives, a number of elements must come together (Crogman et al., 2015). Practitioners must create multi-sensory learning experience in which students interact using their toolkit (Figure 2). Although not obviously stated in Figure 2, active learning pedagogies such as IBL, PBL, etc., must be infused by instructors with multisensory strategies. This will provide the learners with opportunities to explore and ask questions aiding in their critical thinking and problem-solving development (Figure 1, the generated question block). Instructors should:

(1) Strongly believe in the success of all their students, irrespective of their life background and initial performances in the class (Black & William, 1998; Goodwin, 2010; Whiting, Van Burch, & Render, 1995).

(2) Play a central role in modeling question asking (Arnold, 2011; Crogman & Trebeau Crogman, 2016; Crogman et al., 2015).

(3) Be prepared and flexible by being knowledgeable of a wide range of teaching strategies (Bligh, 1971; Christensen, 1988; Hattie, 2008; Penner, 1984).

(4) Promote connectivity and comfortability in the classroom by modeling respect, patience, and deep interest for students (Argyris, 1982; Battistich, Schaps, & Wilson, 2004; Birch & Ladd, 1997; Crogman et al., 2015; Feldman, 1976; Klem & Connell, 2004).

Bonwell and Eison’s (1991) literature review on active learning suggests that it leads to better student attitudes and improvements in their thinking and writing. For example, students perform better when strategic pauses are given (Di Vesta & Smith, 1979; Ruhl, Hughes, & Schloss, 1987), providing opportunities to think, ask questions, or discuss with peers to assimilate and retain concepts. Students also retain information better in the first and last 10 min of class (20% for the first, 70% for
the last), which gave birth to practicing more activities in those times (Hartley & Davies, 1978). Hake (1998), in a pre- and post-test study design, assessed the performance of about 6,000 students in introductory physics courses. It was concluded that performance increased when students were interactively immersed and engaged in class instruction, where their attention is kept online over a wider span. Hake (1998) also found that students’ exams measuring conceptual understanding were higher in classes using active learning than others.

In introductory large classes, lecturing takes place frequently throughout the teaching session along with strategies including defining the meaning of terms, explaining concepts, or providing a demonstration. Lecturing not only includes theories and facts, but also, implicitly, attitudes, and guiding principles in problem solving. In a survey of an introductory physics class using the GQLM, more than 70% of students reported that they preferred a short lecture followed by inquiry exercises, then a class discussion over inquiry exercises, then a discussion. The number one reason given for this preference was the lack of knowledge in understanding their observations. Additionally, discussion sections and laboratory sessions exist to reinforce the conceptual understanding of the subject matter and improve the critical thinking of students through hands-on and active approaches. Part of that process is productive Instructor-Student and Peer-to-Peer interactions around problems to solve. How does the GQLM work in this setting? Figure 7 illustrates that the GQLM framework must be at the foundation of labs, lectures and discussions, to stimulate students’ learning by engaging their exploration, thinking, and their curiosity in a multisensory way. Table 1 provides understanding of the implementation and rationale of the GQLM in the classroom.

4.1. Screening and grouping
At the start of instruction, we recommend that the instructor use a screening test that will allow to determine the base knowledge level of every student. This information should be used to place them in a category of strong, medium, or weak in the subject matter to be taught. In science classes such as physics, this test is known as a CI. According to the results, the practitioner creates mixed groups based on skill levels. Further, the GQLM demands that instructors uses CI tests to identify students’ various knowledge levels, and mathematical strength (or whatever pre-requisites are needed for any subject). Based on these now formed groups, the instructor’s next step is to conceptualize instruction plans and contents that will integrate diverse types of engaging assessments and activities.
### Table 1. Breakdown of GQLM components for effective teaching and learning. To be used for research or teaching purposes

| Tool | Rationale | How to use it |
|------|-----------|---------------|
| **Theory** | Expertise in active learning pedagogies such as IBL, PBL etc. and Critical Thinking activities | Active learning pedagogies keeps the class interactive, and promotes critical thinking in students | Attend specialized trainings and workshops showing a number of IBL, PBL teaching strategies. Relinquish control for allowing more intellectual and physical exploration of the subject at study. |
| | Expertise in Socratic Teaching with Emphasis on Question asking modeling | GQLM makes Socratic question asking accessible to students, even in large classrooms. Learning to ask better and more frequent questions increases critical thinking quality | Announce early that question asking is your objective and teaching format. Warm up student for the first few classes by encouraging to speak out. Reward all interventions, and build upon each students’ questions. Bring up their JTL questions anonymously and show how these questions benefit the class to give students confidence that their interventions are worth being heard. |
| **Unconditional Positive Expectations** | Expecting students, whatever their background and academic levels, to perform in your classroom is the right attitude to have to pull them forward. This should transpire through your attitude, personality, and grading | “I appreciate your comment/question”, “How are you today?” “You had a rough time at the exam? How can I help, I care for your success” etc., these prompts show students they count and are expected to master the class. These implicit interventions profoundly impact students, preventing stereotype threats attached to the way many students expect academics to view them |
| **Atmosphere** | GQLM tenets: Preparedness, Connectivity, Comfortability | Instructors enhance class atmosphere by being ready and flexible, allowing students to feel connected to the material, and classmates, and helping students feel free to learn, ask, and interact | The practitioner must be trained in understanding 1/ various cultural norms, 2/ how to set up dynamic and interactive instruction, and 3/how to create connections through 1-1 interaction and effective communication |
| **Class Format** | Less is more, the GQLM shortens lectures to give more space to practice, discussion, and Socratic questioning exchanges | Lectures should last 10 to 15 mins with interactive activities with clickers questions integrated to help foster discussion and assess real-time learning. Class could start with interactive demos/activities with lectures next. Students make predictions then explore. |
| **Grouping** | The GQLM uses information from the pre-Concept Inventory test to group students. 1 strong, 2 medium, and 1 weak student together. When appropriate, this group will work together on assignments. Performances of the assignment must be used to consolidate or modify the groups in order to keep pushing the bottom tier of the class up. Crogman et al (2015) have shown that keeping the strongest students interested, and pulling the weakest to higher performances. | CI done the first day of class or online with instruction for students to take before the first day of class. Use the information to create groups and help with lecture prep |

(Continued)
| Tool                        | Rationale                                                                                                                                                                                                 | How to use it                                                                                     |
|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| Intriguing Demos           | In the GQLM this is called the “WOW factor”. Numerous research shows that students who are intrigued learn better. Instructors must set up an atmosphere of intrigue at the start and throughout class time to maintain students’ desire to learn. | To introduce the subject of discussion. Ask student to make predictions about the phenomenon. |
| Hands on Practice          | Hands on practice is a direct product of IBL and allows students to explore, be engaged, stay alert and produce meaning from their discoveries.                                                             | Give activities that reinforce lecture or to introduce it.                                      |
| Technology                  | A key feature of the GQLM is the combination of traditional and modern teaching in which technology has a large place. Students from this generation have computers in their hands and show technological expertise and interests which must be harnessed to allow students to feel connected to their learning with items they are familiar with. | Technology helps with drawing students’ curiosity. Clickers used to assess real time learning in class. Web-based interactive pedagogy can be used as an exploration for the subject being discussed. |
| JTL (Just In Time Learning)| Used to foster students’ question asking development. It helps instructors to check the temperature of the class, see where students stumble and address those issues at the next class.                                                    | The JTL is a short questionnaire given at the end of instruction at every class or as often as needed in which students include three things they learned in the lecture, and one question they have. |
| Assessment                  | Pre & post Concept Inventory | This is a major part of the success of GQLM. Instructors must keep good track of progress to make adjustments. The pre-concept inventory tests students’ base knowledge, allows to feel the class’ achievement level, and produce groups which will help pull the bottom tier up while keeping the most proficient students engaged. The post-CI allows to see how the class responded to the GQLM instruction and is more of a research tool, or an indicator for instructors about what would need to be adjusted or how well they did. | Find online, or build your own set of questions which would test the extent of students’ knowledge about the different main concepts covered in class. Note that having to build the CI takes some time. Ask several problem questions, give a choice of solutions, and then ask also what concept the question was about. Add also the possibility to say “I do not know” “I do not remember”. This will allow a more fine tuned data for analyses. Compare the results of pre & post tests to see how efficient your instruction was. |
| Formal and Informal assessment | This is up to the instructor, but some training must be had to understand how to not use constantly the same type of testing in order to give students a chance at different level of examinations, and keep the learning experience multisensory | Again, the trainings and workshops we mentioned early will give plenty of examples of assessments. But this is basically pointing out that students must be assessed with paper/pencil options (multiple choice, matching, fill in blank …), but also orally, through their ability to work in group, through their ability to create, their listening skills and so forth. Not every assessment needs be graded, however they all must be used to provide ample feedback to students and instructors to adjust and improve. |

Table 1. (Continued)
The practitioner should always keep in mind that all teaching methodologies used must: (1) promote comfortability and connectivity, (2) be multisensory by covering most or all learning styles to be practiced by the students, (3) be geared at challenging students’ curiosity in order to promote the learning of critical thinking and in-depth questioning (instructor-initiated content knowledge conflicts for learners to ponder on), and (4) be intentional in helping students learn to be problem solvers.

4.2. Flexibility and delivery
An important factor needed for efficient implementation of the GQLM is the ability to be flexible in the delivery of instruction. Crogman and colleagues (2015) outlined diverse ways to break down class time with models showing how to incorporate both traditional and more interactive teaching methods, while also keeping students engaged and consistently checking on their learning. Other valuable resources can be used to keep these objectives in mind, such as for example, Sokoloff and Thornton (2004) who have provided an eight-step approach for conducting interactive lecture demonstrations that show how to bring scientific inquiry-type of thinking processes into large classes.

Figure 7 shows how to incorporate the GQLM in large introductory courses. Lectures are modified from a didactic standpoint using demos or case studies to engage the learners’ curiosity to promote exploration and question asking. By asking questions and observing students’ behavior, the teacher can assess students’ level of knowledge, which provides the optimum time to intervene in an active learning setting. That is, in the GQLM, it is significant that the instructor knows when to take an authoritative role or interrupting the activity in such cases where knowledge is lacking. The instructor’s mode may change from questioning observed errors, to lecturing about the subject, or clarifying a deficit in students’ behavior or reasoning (Nilsson, Pennbrant, Pilhammar, & Wenestam, 2010).

Free response tools also help to refine students’ learning and improve their interaction. This is the way a teacher can ask questions without intimidating. Morgan (2008) reported that 42% of students enjoyed the anonymity of the clickers, and getting involved with the whole class in the process. Instructors can assess students in real-time, and encourage peer interaction through repolling questions after a discussion.

In short, flexibility is one of the best asset of GQLM instructors. It behooves them to learn as many effective strategies as possible to be able to navigate and adapt to the classroom and keep an eye on progress.

4.3. Using discussion sessions
The discussion session helps students deepen their understanding and problem-solving. We propose to structure a 2 h discussion as follows: the first 45 min must be geared toward easing the students into a work mode by giving well-structured problems which are by definition easier to work out. The last 75 min to explore ill-structured problems (Appendix B) to challenge and improve critical thinking, question asking, and problem-solving skills. This is proposed as a default setting in which the instructor has the autonomy to modify for the best student-learning outcome.

4.4. Laboratory environment
Laboratory exercises help the learner to explore, synthesize, and practice scientific inquiry. Scientific inquiry comes about through the questions we formulate about what we see, hear, read, or do. Any hands-on activity that allows question-asking, exploration, verifying prior knowledge, or leading to new knowledge is considered scientific inquiry. Inquiry can be categorized by four fundamentals: observational, experimental, theoretical, and computational (Wenning, 2011b). Laboratory exercises allow students to use a combination of these fundamentals. This also facilitates the practice of a larger variety of learning styles for each students, and aligns well with the GQLM philosophy.
5. Developing questions and solving problems

Past encounters with problems provide learners with a memory blueprint about their past problem-solving methods. In class, working out problems is a common instructional strategy to model problem-solving skills (Atkinson, Derry, Renkl, & Wortham, 2001). What is less taken into account is the usual memory retrieval behavior of learners, which can crystallize them into methods that may not be very effective. The GQLM is intentional in teaching new and more effective ways to solve problems through question asking strategy learning (Figures 5 and 8).

Let’s take the example of a science class. Basic instruction contains well-structured, stepped, easy to follow problems, all the way to ill-structured complex problems that require more cognitive gymnastics (see Appendix B). A well-structured problem has an easy to discern logic, starting point, aim, and single possible answer (Greeno, 1978; Lovett, 2003, p. 723). Newell and Simon (1972, p. 73) go further by saying that a problem can be called well-structured if the single solution proposed is the only right one, and can be evaluated by an appropriate test. The solution steps are clear and demand the use of simple specific principles, concepts, and rules. Finally, the solution benefits from widespread consensus (Luszcz, 1984). These problems also demand specific skills like recalling, analyzing, breaking down into simple units, finding intermediate goals, and evaluating the result found.

Ill-structured problems on the other hand have been widely studied (Walker & Leary, 2009), especially in non-scientific contexts. These problems are varied in forms, are less specific, less obvious in their organization and direction, and may possess diverse valid solutions, which may not receive consensus from experts (Kitchener, 1983). In a more math-based context, if less variables are given such as numbers or formulas, then applying rules becomes problematic, hence an ill-structured problem. Here, problem-solving skills, are interesting to observe, as students use a garden variety of thinking, questioning, debating and discursive strategies to solve the problem (Meacham & Emont, 1989). In this context, learners must rely more on their understanding of overarching concepts rather than rule and number recall, and become proficient in dividing up the problem between how to represent it, formulate solutions, and test outcomes.

In the end, well-and ill-structured problems require flexibility of the learner, but more so, different levels of understanding of domain specific and domain general knowledge when a problem is simpler and more obvious, versus more higher-order, cognitive-based epistemic skills as in ill-structured problems. GQLM users must introduce these in different forms throughout instruction. It has long been believed that learning to solve well-structured problems will automatically transfer to solving ill-structured ones (Shergill, 2012); however, Schraw, Dunkle, Bendixen, and Roedel (1995) argue that they are independent of each other. It is our proposal however that when one trains in problem-solving by learning constructive critical question asking, it does then hold true that well-structured problem-solving skills will help learners in ill-structured problem solving.

Ideologically and methodologically, the GQLM can bridge well and ill-structured problem specifics. This happens by teaching learners how to use high-level questions which will help in extracting cause, aims, steps to solving, and reasoning behind the solution proposed (Graesser, Baggett, & Williams, 1996). In GQLM we use ill-structured problems to recruit cognitive process of the thinking steps in students (Kitchener’s three-level model, 1983): cognition, metacognition, epistemic cognition. The interaction of L and I-language allows the students to comprehend and perform problem calculations (cognition). The GQLM uses a number of tools for students to self-regulate and monitor their progress (metacognition). Questions become essential for guiding students’ reasoning as they work to comprehend the problem and generate solutions (Figure 8). The GQLM helps students generate questions, which steers their inquiry and influences their thinking, the answers obtained, and the type and extent of knowledge gained. Finally, the ability to generate their own questions is tantamount to them reflecting on the limits of their knowledge, their assumption, deciding on the strategies they will pursue, and the reasonableness of their answers (epistemic cognition).
Instructors must model and help students ask productive questions that can advance their thinking, organize, and consolidate what they have learned (Figure 8). This helps consolidate adequate thoughts related to the concept studied, and creates an improved blueprint in the memory, which equips students with better problem-solving tools. When students document their learning journeys with their questions and ideas, they become more progress-driven as they watch how their knowledge of the topic evolves and increases along the way.

Instructors using GQLM may introduce a topic and start first by motivating students to formulate what they would like to know about a given topic. In doing so, students would make their inquiry
explicit, which allows practitioners to build upon their base for instruction (Figure 8). This creates a GQLM interactive framework where students are not passive in their now complex and intriguing learning experience. These types of activities promote discussion among students and keep them motivated to learn more.

Instructors should be intentional in starting with well-structured exercises so as to not turn off students, but should move to creating interesting and relatable ill-structured problems (Appendix B), which demand time and creativity, but can be extremely rewarding when students achieve their learning goals.

6. Assessment in the GQLM

When assessments emphasize on the skills, knowledge and attitudes, the learning process becomes more effective (Crooks, 1988). Black and William (1998) posit that “assessment in recent years has been the shift in the focus of attention, towards greater interest in the interactions between assessment and classroom learning and away from concentration on the properties of restricted forms of test which are only weakly linked to the learning experiences of students.” Crooks (1988) also argues that feedback to students is beneficial when it is focused on the task, and must be given regularly, be relevant, and be specific to the task.

In the GQLM, instructors are central to the assessment of learning through the use of multisensory pedagogies which are needed to (1) engage student’s curiosity, (2) develop students question asking ability, and (3) improve student learning. Instructors using GQLM should focus on assessing progress in these three areas.

The need for more standardized and measurable research-based methods is paramount in order to recommend any instructional strategy in a valid and replicable framework. Instructors typically shy away from using active learning curricula because of the accountability pressures, and their beliefs about efficiency in having to cover science content to help students prepare for high stakes standardized tests. Thus, instructors resist, stating that methods such as IBL/PBL activities are a luxury that they cannot afford, given their time limitations (Chin & Chia, 2006). Crogman and colleagues (2015) show that in the Finnish school system’s content is rather sacrificed for greater understanding. This pedagogy has shown to produce better performance overall, and on world ranking standardized testing. The GQLM follows this philosophy and blends the essentials of active learning with didactic teaching, in a more balanced pedagogical set-up, through question-asking inquiry. Thus, this is preparing for the standardized testing more successfully by boosting critical thinking.

Hands-on assessments provide a better perspective on what has been learned than testing skills through essays or interviews, which may be better suited for checking learning of more theoretical knowledge (Wenning, 2011b). The GQLM upholds flexibility and adaptability as a capital characteristic of instructors who need to master how to make use of Socratic (learning by question asking modeling), Hands-on activities (physical experiences and experiments, grouping, discussions, demonstrations), and Didactic (teacher stands and delivers lecture) teaching strategies to enhance the learning experience. The GQLM promotes using technology (clickers, PHET, online demonstrations), traditional assessments, and flexible time and activities in large and small classes. It focuses on developing Critical Thinking, Question asking, Interactivity, Connectivity of students with the instructor and classmates, and Comfortability with the classroom and the learning process.

There must be diverse assessment strategies that correspond to these types of teaching practices to evaluate the merits of implementing a GQLM in the classroom. As mentioned before, all assessment types are not valid to test all types of learning behaviors and performances. Practitioners must be flexible in their testing strategies using conventional and alternative non-conventional testing and assessment practices. To study the effects of the GQLM on learners, we recommend using these different assessments before, during, and after the implementation of the model. If possible, at a minimum, doing so over a class period such as a semester or a quarter is ideal.
Standardized written exams, by virtue of their format, do not allow to specifically track acquired skill processes learned. For instance, the use of pre-and-post-tests works for testing the acquisition of knowledge, but is less efficient to bring to light the acquisition of skills (Gibson & Shaw, 2010). Also, such skills as communication should rather be observed in situ and live while assessing their organic application. However, “the efficacy of oral interview is also questioned depending on what knowledge or skill” is tested as we brought up earlier (Gibson & Shaw, 2010). Thus, pre-and-post tests should be used to assess basic knowledge that equips students to learn and understand more complex knowledge and skills in a discipline. Some researchers (Crogman et al., 2015; Oros, 2007) determine the value of an active-learning exercise through the use of standard course evaluations completed by students at the end of the semester.

Certain aspects of the origins of what is now the GQLM were piloted to test its performance and quality when applied to freshman physics classes (Crogman et al., 2015). A Concept Inventory (CI) test was applied pre- and post-instruction to assess the basic knowledge of the students before and after the application of the GQLM. These tests were used to gather information about learning achievement, self-efficacy (capacity to feel confident about one’s ability to learn the subject matter and fulfill the assignment and tasks related to that subject) (i.e. Schunk & Ertmer, 2000; Zimmerman, 2000), and self-regulation (autonomous motivated and aimed behavior in solving problems and asking question to reach a goal) (Paris & Paris, 2001; Zimmerman & Schunk, 2001). Class satisfaction evaluation forms and questionnaires were also used to gather feedback from the students about the learning model implemented during instruction. The following indicators were evaluated:

1. Self-regulated learning
   • Evaluation and comparison of pre vs. post responses on self-regulation specific questions, and classroom behavior (autonomy, question asking quality, persistence in problem solving).
2. Self-efficacy in learning
   • Evaluation and comparison of pre vs. post responses on self-efficacy specific questions, and personal behavior (pre- and post GQLM confidence with the subject matter, motivation behavior, belief about the quality of one’s work and satisfaction ratings with one’s evolution in learning throughout the course).
3. Comparing of student’s achievement scores pre-and post GQLM application

Research has shown that learners with low self-regulation and self-efficacy have tremendous difficulties with problem-solving (Pajares, 1996). CIs should be used to assess students’ prior self-regulated abilities since self-regulated learning is related and dependent in many ways to content knowledge (Zimmerman, 2002). Preliminary results in Crogman et al. (2015) showed a positive increase in students’ critical thinking ability (as observed from students’ survey data and problem-solving ability outcome).

One of the most fundamental pillars of the GQLM is the change in curiosity levels in students as it relates to question-asking. This aspect was not investigated in the pilot study and remains to be assessed to demonstrate the true effectiveness of this model. Nevertheless, JTL as described by Crogman et al. (2015) was used to evaluate students’ development in question-asking (and by extension curiosity) through their overall interaction in the classroom.

6.1. Pre-instruction assessments
Curiosity is fundamental and directly associated with students’ exploratory behavior and question asking development. Multisensory pedagogies fostering curiosity can be measured in a number of ways. For example, we propose to enhance the JTL (EJTL). It is a descriptive explicit feedback for students helping them in learning and grasping concepts (Friesen & Scott, 2013). It is a formative assessment loop in the GQLM that acts as a measure of students’ question asking development.
large body of research concurs that formative assessments’ impact is large for students’ learning progress (Bransford, Brown, & Cocking, 2000; Darling-Hammond, 2008; Hattie, 2008; Heritage, 2010). We expect that the use of EJTL will correlate with an increase in students’ curiosity and question-asking in the classroom. The effective use of question asking will correspond to students applying knowledge and creating new knowledge to solve problems. We will now discuss how we can assess these outcomes in the GQLM.

Before instruction begins, there must be an assessment of (1) curiosity levels, either through a survey with vignettes and problem situations, or through observation in group situations; (2) the question asking behaviors (frequency and quality of questions) must be observed for each student, this can be done in different ways depending on class size, either by mere observation (with a rubric), or by collecting students questions on paper, or with technological tools such as free-response, class recordings, or online forums; and (3) critical thinking skills, again here observation, discussion, and/or paper-pencil questionnaires and games (for example, constructed on the basis of Bloom’s taxonomy), accompanied by oral assessment through Socratic techniques, can give a clear view of each students’ skills and of the overall class level as well.

Finally, recall that one of the claims of the GQLM is that all students possess all learning modalities, that they are tools students own, which must be enhanced and developed to make them well-rounded learners. On that premise, instructors must devise a way to assess these styles in order to be able to test after instruction how these skills may have evolved. This can be done by the use of standardized learning styles testing kits such as learning styles inventories, the VARK questionnaire (Fleming & Mills, 1992, Leite, Svnicki, & Shi, 2010), or other existing paper or online tests. This can also be achieved by instructors creating their own tests, based on the subject matter, making sure to include questions covering all the known learning modalities (Crogman & Trebeau Crogman, 2016).

6.2. During-instruction assessment

Here, a merging between conventional mid-terms and other traditional and non-traditional strategies is needed in order for the instructor to monitor learning evolution and adjust instruction according to the pace of the class. Other strategies must revolve around studying group behaviors by assigning hands-on tasks and giving feedback, and creating opportunities for students to work together and evaluate each other (Manis, 2012). These peer evaluations allow to keep students engaged, motivated, and to learn to receive constructive feedback to grow and get a better sense about how their work and behavior are perceived. Instructors should also not shy away from randomly calling students (who should feel comfortable to come to the board if the instructor followed the GQLM philosophy of comfortability and connectivity), checking on the changing quality of discussions through Socratic interactions and in discussions. Finally, one must assess the quality of responses on clickers real-time questions, checking overall learning at a minimum with EJTL and other tools that help keeping track of each students’ evolution with their questions and levels of understanding.

6.3. Post-instruction assessment

Finals are the common strategy known to assess if instruction has been successful. Keep in mind, however, that finals do not necessary have to be paper-pencil based. Instructors must use multiple tools such as group work presentations, online forums and interactive exams, games, asking students to create a project, requiring students to come up with questions and assess the quality and depth of these generated inquiries, and so forth. Instructors should not refrain from being creative and devising assessments that may not give a grade necessarily but that will give a clear view of what the students have learned in terms of general knowledge, but also more fundamental skills as learners.

To conclude this overall assessment section, instructors must at the end of instruction re-use the assessments they chose at the pre-instruction stage to be able to have pre/post comparison data. This should allow instructors to create simple statistics to show how students have responded to the
GQLM's philosophy. Additionally, course evaluation and analyses evaluating the perception of students (on comfortability, connectivity, preparedness) are recommended to give the instructor a real sense of the students' experience beyond that of content learning. This provides feedback to improve the GQLM implementation and further instruction.

6.4. Preliminary results and discussion

We have operationalized the impact of GQLM on student learning and motivation as the following indices:

(1) Positive review of students (comfortability, connectedness) and sense of appreciation for learning
(2) Peer faculty positive evaluations of class conditions
(3) Students' questioning quality
(4) Students' behavior within a dynamic teaching framework (i.e. interaction with demos/prompts/technology)
(5) Average scores differences between pre- and post-instruction FCIs

With the implementation of GQLM, we observed learning progress as:

• Students' abilities (and increase) in asking targeted questions showing critical thinking,
• Students' ability to use concepts learned within different lecture contexts and ability to connect them,
• Students' questioning quality,
• Student's recall of information on demand,
• Students' ability to explain concepts, and quality of their proposed solutions to solve problems.

We are also looking to observe progress or development of curiosity in terms of how students request more information and additional resources, how they grow in their question asking, how they interact with the problems and demos given, and if they stay at the level of the work done or push beyond by their questions or actions. Table 2 shows two classes of examples of implementation of what may take place in a GQLM classroom with a multi-sensory approach linking Didactive and Active teaching strategies. We will provide and discuss the results for the physics examples.

We compared a GQLM-based class and a regular class on a number of measures. The class sessions were three-hour periods. The regular class had an hour lecture followed by laboratory, while the GQLM class was more fluid in its sections and activities breakdown (see Table 2). The student (L)/teacher (I) interaction revealed the impact language has on instruction. Through the effect of positive relationship significant learning arises (Corner, 2001). When instructors strive to build relationships it is more critical that they seek to understand their students first than they be understood by their students (Covey, 1989). I-language is then formulated to grasp the context of L-language through that relationship. To measure these interactions between L- and I-language we looked at the results from students' responses to survey questions on their comfortability and connectivity with instructors and peers. We looked also at how familiar they were with the examples used to explain class concepts as compared to their everyday experiences. We looked at instructors' responses assessing their students' storylines and how they used it in the classroom for the students' comfortability and familiarity. This helped to bridge language gaps in the classroom where students did not find their instructors distant and unapproachable.

In our preliminary survey, 90% of the students reported that the classroom environment was comfortable and that they felt connected to the instructor in the GQLM-based class, corroborating Crogman and colleagues’ (2015). Analysis of faculty evaluations of both classrooms revealed that
Table 2. Breakdown of GQLM-based teaching (blending didactive and active learning strategies through multisensory pedagogies)

| Discipline | Concept       | Didactive pedagogy                                                                 | Multisensory pedagogy                                                                 | Active learning pedagogy                                                                 | Feedback                                                                 | Conclusion                                                                 |
|------------|---------------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Physics    | Falling objects | Do heavier objects fall more slowly than lighter objects? Demo: Two objects of close masses are dropped and time is noted. Which hits the ground first? Two objects of different masses fall and time is noted. Which hits the ground first? This demo creates conceptual conflict between classroom teaching and students' experience. Students are asked to write down questions to discuss in groups. Theory: If an object is heavier the force of gravity is greater, but since it has greater mass the acceleration is the same, so it moves at the same speed (neglect air resistance). If we look at Newton's second law, \( F = ma \). The force of gravity is \( F = mg \), where \( m \) is the mass of the object and \( g \) is the acceleration due to gravity. | IBL: Six stations are set up to explore this question. Students will drop two objects of different masses in various fluids of different viscosities (Air, water, oil, and honey), and note the fall time difference. Students are then asked to plot the density vs. the difference in time on a graph, and note the time difference behavior as they go from a more viscous fluid to a less viscous one. Clicker Questions followed by discussion in groups (with neighbor) and then individual re-poll. | Demo: Allowing the object of different to fall in a vacuum. Equating, we have \( mg = ma \). That is, \( a = g \), if there was no air resistance. Therefore, a feather would fall at the same speed as a rock. | EJTL: Students responses observed | (Continued) |
Table 2. (Continued)

| Discipline         | Concept                                           | Didactive pedagogy                                                                 | Multisensory pedagogy                                                                 | Active learning pedagogy                                                                 | Feedback                                                                                   | Conclusion                                                                                      |
|--------------------|---------------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Cognitive psychology | Mechanism of psycho-physical perception in vision | Short lecture on perception: establishing the cognitive and physical processes involved in perception. Connection with consciousness, emotion, expectation, biases, priming. Examples of illusions (i.e., rotating snakes, the backpack and hill experiment), and connection to human behavior. | Presentation of a colored still image with a dot in the middle that students have to focus on (30 s). Then the color suddenly fades to black and white, but students still see color on the picture. As their senses are confronted with the discrepancy, they slowly can see the color fade away. | Students write a few questions they have about the phenomenon they just observed (set that aside). Have you seen color when it wasn’t there? (Yes/No) - notice individual differences. What structures do you know are involved in vision? (go over an interactive brain online where students can interact with brain parts and exchange on which centers are involved), then discussion in general class. | Back to didactive mode with a brief presentation of the official color vision theories, a word of how the discovered effects can interfere with psychology (witnessing, fear, navigation.../...). | EJTL: Students response observed. Classroom Concept Demo Survey (CCDS): Students feedback on concepts, ill-structured problems, and their curiosity. Ill-structured problems: Reflection on assumptions, strategies and reasonableness of answers. |
evaluations the GQLM classroom ranked highly students/instructor relatedness and the level of interaction among the students.

We used the EJTL as a way to assess the quality and increase in students’ questions. EJTL provides feedback on the impact of lesson presentations on students’ curiosity. Thus, students showed an increase over the course of the semester in question asking although this was also the case in classrooms where the GQLM was not implemented (control group, CG). Further EJTL and CCDS both revealed that more than 75% of students found that prompts and attention grabbers used in the classroom made it easier for them to ask questions. They also felt that these prompts drew their interest in the lesson. However, the difference was noticeable in the amount and type of students asking the questions (for example, not just by the best students, or the more talkative).

Further, in the GQLM-based class, more attention-grabbing prompts and activities were used to draw out students’ curiosity. They responded positively to this sensory learning focus, by indicating their liking of the activities. As pointed out before, curiosity was correlated with level and quality of students’ question-asking. Additionally, from CCDS’ data, most of the students in GQLM-based instruction found ill-structured problems helpful since they made the lesson activities fun. The use of ill-structured problems in class instruction (Table 2) made for effective collaboration between students, and questions arose naturally out of this exercise. About 43% of students reported that ill-structured problems helped improve their question asking abilities.

Finally, the performance of both classes on the pre-instruction FCI was similar (CG: \( n = 20, M = 8.1, \) \( SD = 4.02 \) and GQLM: \( n = 28 M = 9.9 \) \( SD = 5.48 \)), but post-test FCI results show that GQLM students performed better (CG: \( n = 20, M = 11.2, SD = 4.28 \), effective size \( d = 1.21 \), average gain = 0.17; and GQLM: \( n = 28 M = 17.5, SD = 4.44 \), effective size \( d = 1.52 \), average gain = 0.37). The GQLM’s effect size (1.29) was larger than the CG’s (0.38). An effect size of 0.25 or bigger is considered to be statistically significant (Cohen, 1988). Moreover, effect size measures provide a standard metric that meta-analysts and others can interpret across studies that vary in their dependent variables as well as types of designs (Maxwell & Delaney, 2004). Thus, considering the preliminary result obtained, GQLM shows promise as a valid instructional model. Data are still being collected and will be presented fully in a manuscript over the course of the upcoming year.

Table 2 shows that a multisensory pedagogy can be linked to didactive and active-learning pedagogies, and we see that instruction can move easily between them. We highlight here again that the depth of active learning is based on levels of prior knowledge. That is, the more prior knowledge the student has, the more the instructor can facilitate independent inquiry. This means that less prior knowledge brings a need for more didactive teaching. GQLM uses CI to determine the students’ knowledge levels and plan how their teaching pedagogy should then unfold. The strength of the GQLM comes in how well the practitioner interacts with the students while fostering multisensory learning that bring the learners to generate their own questions into inquiry or from inquiry. Thus, GQLM instructors potentially provide the students with the tools for their own exploration by listening to their L-language, and create a curriculum that does not stifle students’ creativity. Washington Carver once said that all learning is fostered through relationship building (McMurry, 1981), which is at the heart of GQLM. Students/instructor relationships work best when the language used is familiar to all parties and this is the job of the GQLM instructor in their interaction with their students and community from which they come from (Crogman, 2017). It is in this environment that students are not afraid to be wrong and take more risk with their questions.

These exploratory results are showing promise. Students feel well in the GQLM environment, other faculty observing from an outsider point of view noticed the same. Additionally, students improved in general knowledge but also in question asking and critical thinking skills, while FCIs show concrete evidence of larger grade improvement at the end of a semester. We aimed at implementing a model that is fundamental to the basics of learning (using well-known teaching strategies and borrowing from didactive strategies), while looking forward (embracing empirical research, innovative
strategies, and less traditional teaching delivery), in order to wake up students from an educational consumer habit behavior, to becoming alert inquirers and loving to be in class (Table 2). We look to replicate the study over several years, in different classes and schools contexts, and with a variety of educators to confirm the trends observed. We believe that this approach can help educators assess more easily their class knowledge and skill levels, create better structures to support the weakest students, and immerse students in an environment where most barriers to learning are broken down to help them wanting to absorb information, understanding it, and seeking for it more readily. With the addition of more empirical testing, we are designing a GQLM implementation manual that could become a tool for schools of education, and instructors seeking for a structure to learn and implement in their classrooms. The model does require some preparation on the part of instructors whom we expect to become more knowledgeable of diverse teaching tools, in order to know when to switch strategies, when to ask question provoking questions, and how to appreciate their students better.

7. Online implementation of GQLM

In Young (2006), college students who took online classes were surveyed to find out what, in their opinion, were the most effective factors in their learning and liking of the online classes they enrolled in. The top factors were the flexibility of the instructor in adapting to their needs, the use of real life examples, the explicit strategies to motivate them to do their best, the instructor’s ability to facilitate the course effectively, meaningful contents and expectations seen as important for their growth, effective communication, and a display of genuine concern for student. As detailed in the— Features of GQLM Format—section, these factors are clear attributes of the GQLM.

Implementing this model online, could include a focus on tasks given after short lecture video presentations. Students could be asked questions in interactive forums. They could also be trained on how to pose both low- and high-level order questions, and explain how they have addressed or explored their solution. Then these questions could be shared in the discussion forum for the class input and constructive conversation moderated by the instructor.

GQLM could be used online by practitioners, setting aside the physical contact difference between a regular classroom and an online class forum. We invite researchers to explore these venues, and compare the benefits of both GQLM-based live classrooms and online classes.

8. Limitations

This model is based on the practitioner’s centrality to create an environment that is comfortable and motivating to students. Thus, any situation where the practitioner would lack (1) training in various pedagogies or active learning strategies, (2) sensitivity to cultural norms, or (3) belief in their students’ success, would render this model non-effective.

As we mentioned also, there are a number of difficulties faced by active models, thus the GQLM making use of active learning strategies could face some of these challenges. However, GQLM is designed, to lower or minimize these risks due to: instructors being trained to be flexible, the teacher–student relations, and the hybrid nature of the model. For example, the GQLM uses short learning strategies to minimize the risk of wasting class time, and because it is an active model there is the problem of covering enough content; the hybrid nature of the model content is still covered such that lectures are balanced with inquiry. We mentioned that instructors may complain about class prep for activities; this is a framework to become used to, and the short lecturing takes away some of the prep load by providing concepts and information that then do not need to be discovered through inquiry. We thoroughly addressed the issue of active learning in large class sizes. In the GQLM, the use of technology allows whole classes to participate in activities that are engaging, and the constant care taken to develop relationships with the students gives them the desire to stay engaged and connected. Students in this instance would resist less this unusual teaching style because of that relationship and also because within the newness of active learning methodologies, they would also recognize the regularity of didactic lecturing.
Finally, the FCI tests scores reported between the control and GQLM classrooms was done by the same instructor, as such, more research is needed controlling for that. Further, implementing the GQLM may be at first time costly and require strong initial efforts of organization and willingness to become versatile on the part of instructors, but initial investment has shown a positive payoff. More research is needed to test the model and confirm the trends observed. Such improvement as introducing the GQLM concept in Education programs, may be a perspective to consider in the future.

9. Conclusion
The Generated Question Learning Model (Crogman & Trebeau Crogman, 2016) is a modified version and shall we say, a tentative to improve what was coined Pseudo Socratic Teaching (PST) (Crogman et al., 2015). It focuses on the development of question-asking skills in students by considering ways to engage their curiosity through pedagogical multisensory stimulation. In this essay, we outlined the major features of the GQLM for educators to understand and apply in their classroom. The GQLM’s impact has been pre-assessed and shows potential success for student learning. We outlined how to assess this model’s impact on teaching and learning. Future work will propose outlines for teaching degrees and higher education curricula and programs, on how to train educators in the model.

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### Appendix A

| Emphasis                          | Reasoning and critical thinking which usually requires some direction from the instructor |
|----------------------------------|----------------------------------------------------------------------------------------|
| What is required of the student? | Demonstration of understanding and ability to apply the information (students describe, compare, contrast, rephrase, summarize, explain, translate, interpret or provide an example) |
| What Cognitive Operations are involved? | Explaining, stating relationships, comparing, and contrasting |
| What typifies these questions?   | Students will look for evidence to support their response, and may break ideas, situations or events down into their component parts |
| Signal Phrases                   | Why, how and in what ways |
| Example                          | “In what way do plant cells differ from animal cells?” |
| Aligned to Bloom’s taxonomy of learning | Comprehension and application levels |
| Pros                             | Helps students to make connections between facts and begin to understand relationships. Fosters critical thinking and skills such as comparing and contrasting |
| Cons                             | Can lead to digressions in lesson plan, answers are longer and more elaborate and may not be easily anticipated by teacher |

McComas, W., & Abraham, L. (2012). *Asking more effective questions. Rossier School of Education.*

**Lower level convergent**

| Emphasis                          | MemORIZATION, recall, rote drilling |
|----------------------------------|-------------------------------------|
| What is required of the student? | Recall or recognize information (identify or name, quote or define) |
| What cognitive Operations are involved? | Call for the transfer of information in predictable ways. Questions at this level will determine if students can organize and select facts as well as state the main ideas |
| What typifies these questions?   | Answers are easily anticipated by the teacher and are often closed—requiring a “yes” or “no” answer. Questions found at the back of the textbook chapter are typically low-level convergent questions |
| Signal phrases                   | Who, what, where, when |
| Example                          | “According to our study of plant physiology, what conditions are required for photosynthesis to occur?” |
| Aligned to bloom’s taxonomy of learning | Knowledge level |
| Pros                             | Easy to develop questions and to anticipate student responses, so directing class discussion becomes routine. Helps identify students with large deficits in general knowledge |
| Cons                             | Least effective method for enhancing knowledge transfer. Students who respond correctly may have memorized material but without understanding it |

**Higher level convergent**

**Lower level divergent**

| Emphasis                          | Synthesis of information and analysis of information to develop response |
|----------------------------------|------------------------------------------------------------------------|
| What is required of the student? | Think critically about information, ideas, opinions. Students discover motives, reasons or causes, draw conclusions, inferences or generalizations |
| What cognitive Operations are involved? | Hypothesizing, reconstructing |
| What typifies these questions?   | Questions that ask students to think of alternative ways of doing something, or require them to synthesize a number of elements to create an original idea |
| Signal phrases                   | How could ..., What are some possible consequences ..., Imagine... |
| Example                          | “How might life be different if peace was declared in the middle east?” |
### Aligned to Bloom’s Taxonomy of Learning

| Analysis Level (Pros) | Analysis Level (Cons) |
|----------------------|-----------------------|
| Focuses on critical thinking skills and allows for in-depth student discussions. May lead to more student-generated questions and conversations thus engaging the learner at a deeper level. | More difficult for teachers to determine in what direction the lesson might be drawn. Requires more pre-planning, energy and effort on behalf of the instructor. |

### Higher Level Divergent

| Emphasis | Motivate students to higher levels of thinking and encourage creative thinking. |
|----------|--------------------------------------------------------------------------------|
| What is required of the student? | Students produce original communications, make predictions, propose solutions, create, solve lifelike problems, speculate, construct, devise, synthesize, develop/judge ideas, problems solutions, express opinions, and make choices and decisions. |
| What Cognitive Operations are involved? | Predicting, inferring, performs original, creative and evaluative thinking. |
| What typifies these questions? | Teachers are required to think of the content they are presenting in different ways by creating different contexts for learning the material. |
| Signal Phrases | Defend, Judge, Predict, If... then, Can you create, What is your opinion... |
| Example | “Suppose you are the President of USC. How would you devise a plan to increase the retention rate of minority first-year students?” |

### Techniques for Successful Questioning

| Phrasing | Teacher communicates the question so that the students understand the response expectation (i.e.: no run-on questions) |
|----------|----------------------------------------------------------------------------------------------------------------|
| Adaptation | Teacher adapts the question being asked to fit the language and ability level of the students. |
| Sequencing | Teacher asks the questions in a patterned order indicating a purposeful questioning strategy. |
| Balance | Teacher asks both convergent and divergent questions and balances the time between the two types. The teacher uses questions at an appropriate level or levels to achieve the objectives of the lesson. |
| Participation | Teacher uses questions to stimulate a wide range of student participation, encouraging responses from volunteering and non-volunteering students, redirects initially asked questions to other students. |
| Probing | Teacher probes initial student answers, and encourages students to complete, clarify, expand or support their answers. |
| Wait Time (Think Time) | Teacher pauses three to five seconds after asking a question to allow students time to think. The teacher also pauses after students’ initial responses to questions in class. |
| Student Questions | Teacher requires students to generate questions of their own. |
Appendix B
Examples of ill-structured problems in diverse disciplines.

Defining ill-structured problems
The best ill-structured problems are found in real-life examples to which students can relate, and have the latitude to explore different ideas based on their prior knowledge. In these types of problems, there are no obvious right answers, solutions or rules, and clear goals or available information (Howard, McGee, Shin, & Shia, 2001; Wood, 1993). These problems allow for flexible thinking with the possibility of finding several right solutions and answers (Meacham & Emont, 1989).

Ill-structured problems for Physics
A. Astronomical observations show that the planet Venus is entirely covered in cloud, so that the Venusians are unable to observe the heavenly bodies. Describe how they could accurately measure the length of their day.

B. A small object is at rest on the edge of a horizontal table. It is pushed in such a way that it falls off the other side of the table, which is 1 m wide, after 2s. Does the object have wheels?

C. To protect passengers in car crashes, air bags can be used, which are rapidly filled with gas and absorb the impact. Assess the effectiveness of this technique. If a vehicle moving at 100 km/h crashes, and a person’s head striking the bag is injured, what must be the size of the bag and the gas pressure in it?

Ill-structured problems for Chemistry
A. Kinetic models based on experimental data are being used increasingly in the chemical industry for the design of catalytic reactors. However, the modeling process itself can influence the final reactor design and its ultimate performance by incorporating different interpretations of experimental design into the basic kinetic models. In this problem, students are asked to develop kinetic modeling methods/approaches and apply them in the development of a model for the production of methanol from experimental data.

B. In Thailand alone, snakebites are responsible for the deaths of approximately 2,500 people a year. The interaction of snake venom with newly-developed antivenoms in the human body can be modeled as a chemical reaction engineering catalysis problem. Students use this knowledge to create and solve unique snakebite scenarios.

Ill-structured problems for Biology
A. In a fit of teen-aged angst (which we grown-ups call stupidity) you have shaved your head. Your hair is mainly composed of the protein keratin. Assume that keratin is an exported protein. Describe the process that must occur inside a hair cell to produce and export this protein to begin re-carpeting your bald head.

B. Which of the main psychoactive drugs is the most dangerous? (answer: it depends—answer depends on age, gender, level of disorder, health condition, weight.../...
Ill-structured problems for theology/religious education
Today's liberal democracy presents a resistance to religious dogmas and calls for the religious enti-
ties to shape the social discussion in the contexts of race relations, sexuality, gender identity, pov-
erty, crimes, etc. Discuss a stepwise proposal that would call upon the church to play great role in
political advocacy without betraying their theology or becoming political to the point of diverting its
essence and mission.

Ill-structured problems for Mathematics
A. A rectangle has an area of 120 cm². Its length and width are whole numbers. a. What are the pos-
sibilities for the two numbers? b. Which possibility gives the smallest perimeter?

Brain teasers and interdisciplinary problems
A. This problem requires the subject to tie two hanging strings together although one cannot be
reached while the other one is held.

B. Two communities exist on either side of a river and only a bridge that connects them. The bridge
is the only road into one of these communities and all most every year, when the river rises, the bridge
collapses. The bridge was rebuilt a numbers of times, and at various height without avail. Design a new
bridge that would withstand the yearly rising of the river.