Incorporating Interest Development, Self-Determination Theory, and Flow into Guided Inquiry Design in STEM Environments

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In an information science context, inquiry is related to information seeking. When problems are encountered, there are personal or professional motivations to fill them. Inquiry-based learning is a student-centered pedagogy in which students question and explore situations, charting their own paths toward solutions (Maaß & Artigue, 2013). Inquiry becomes *Guided Inquiry* (*GI*) when Kuhlthau's six-stage, three-domain information search process (ISP) model is used as the theoretical backbone of developing instructional supports for the inquiry process of learners, often in classroom or library settings. Kuhlthau's (1991) ISP is a widely used and broadly accepted interpretation of the information search process in a constructivist learning environment. *GI* is a pedagogy derived from the ISP featuring a pattern of discovery that aligns with the stages of the ISP and that includes specific instructional scaffolds and activities, designed by the educator/school librarian, to elicit a set of practices, behaviors, and learning outcomes in students. I hypothesize that it can be complemented by interest development models such as Hidi and Renninger's *Four Phases of Interest Development* (2006), and psychological theories such as *Self-Determination Theory* (Ryan & Deci, 2017), and *Flow* (Csikszentmihalyi, 1990).

Kuhlthau, Maniotes, and Caspari (2015) published the definitive work on *Guided Inquiry*, the educational pedagogy developed from Kuhlthau's ISP, incorporating "third space," the learning space in which the curriculum meets the personal experiences of the students. This is the constructivist realm in which students dwell, hopefully working in the psychological state of *Flow* (Shernoff, et al., 2014; Csikszentmihalyi, 1990), engaging each other and the content, beginning to scaffold relevant knowledge and understanding (Kuhlthau, 1991; Kuhlthau, Maniotes, & Caspari, 2015; Reiser & Tabak, 2014). *Guided Inquiry* is collaborative, engaging, reflective, and iterative, as students explore new ways to solve problems, answer

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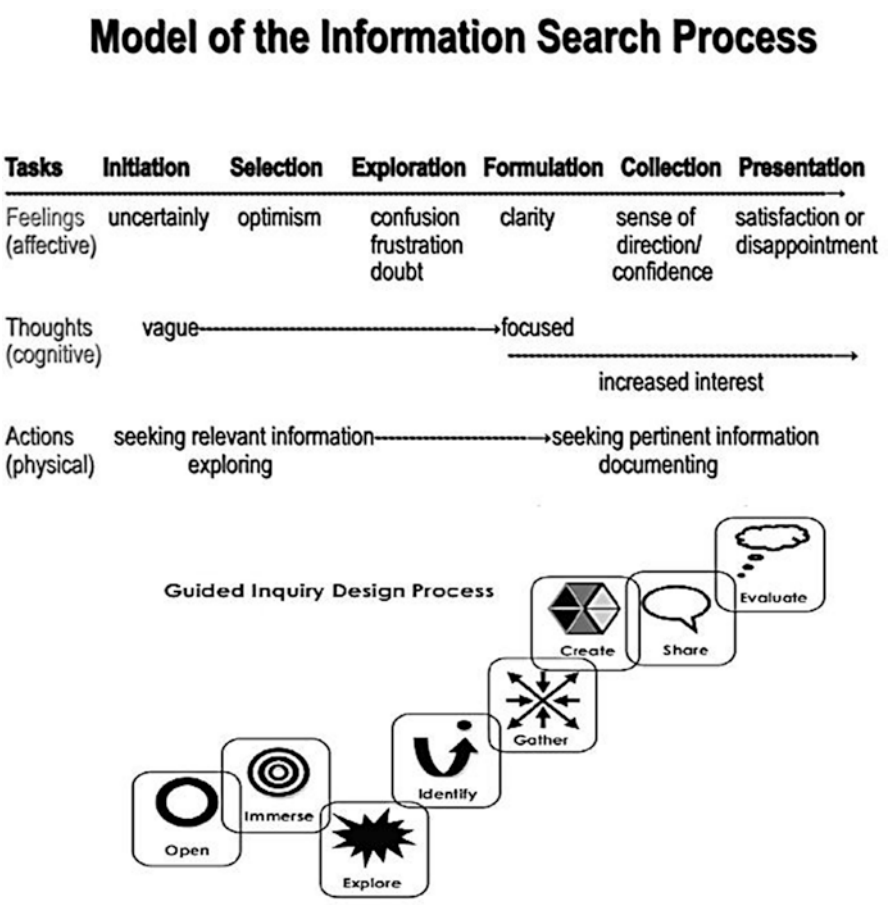

Fig. 1 Kuhlthau's (1991) Information Search Process model aligned with the Guided Inquiry Model (Kuhlthau, Maniotes, & Caspari, 2012)

questions, and create authentic artifacts. Motivation, interest, and engagement are primary factors in engaging in GI-based learning. Figure 1 below displays the development from the six-stage, three-domain ISP to the *Guided Inquiry Design* (GID) pedagogy. The tasks in the ISP are closely aligned with the stages of the GID, and they flow in the same direction, sharing many of the same qualities. The GID is different from the ISP in that it is a pedagogical innovation, a full educational unit designed to successfully engage in an inquiry-based project. The ISP provides the theoretical backbone for the GID.

Motivation, interest, relevance, and affect are primary factors in engaging in *GI* learning, especially since personal relevance to content is one of the tenets of *GI*. However, interest and affect, especially as it relates to social relatedness (Ryan & Deci, 2017), could play an even more central role in *GI* and the *GID*, with continued research. I will propose three general observations/conjectures on these

potential intersections. Overall, I conjecture that interest, motivation, and engagement intersect with ISP, the *GI*, and the (*GID*) models in the following ways:

Firstly, situational interest-driven searches for information and individual interest-driven searches for information will look and operate differently, with different processes unfolding that are not accounted for by the present ISP. Situational interest may or may not include engagement, while individual interest always does (Renninger & Hidi, 2016). Situational interest usually involves facilitation (Abbott, 2017) and may or may not be interesting to the searcher, while individual interest is intrinsically motivated or internally regulated and produces self-efficacy leading to expertise. However, the ISP treats all information searches the same, unable to account for issues such as low motivation due to lack of social relatedness or amotivation and "going through the motions" (Deci & Ryan, 2008). The ISP characterizes all searches as experiencing the ups and downs of the extended search experience charted across the ISP model. The ISP assumes engagement will be persistent throughout the search and retrieval process, motivation differentials will not enhance or interfere with the process, and interest will increase as students become more knowledgeable about their topics through formulation and collection.

For situational interest, much more emphasis would have to be placed upon the beginning of the ISP. Much of the impact of situational interest is at the beginning, the hook or novelty that catches students' attention. There would have to be a trigger or Open phase to the ISP during which an anticipatory set can activate schema, and knowledge would have to be built and contextualized before the main inquiry began. However, if individual interest were tracked, I hypothesize that the first stages of the ISP would be virtually unnecessary since students know what they like. The affective track would change in that feelings of uncertainty, optimism, confusion, frustration, and doubt would be replaced by the confidence and sense of direction of the later stages of the ISP. The physical realm would have less of a transition between relevant and pertinent information since the student already knows and likes the material.

Secondly, perceived competence, autonomy, and relatedness interact at several points with the ISP-process aspects of cognition/affect/behavior. Most research projects begin with an external assignment, in this case an external regulation (Ryan & Deci, 2017; Cook & Artino, 2016). As students work through information search and retrieval, Kuhlthau (1991) predicts they will achieve increased interest cognitively and confidence and direction affectively while physically moving from finding relevant information to finding pertinent information. *SDT* aligns with these movements through competence and somewhat through autonomy, but not through relatedness; there is little accommodation in the ISP for student collaboration in teams. Words like clarity and focus on the ISP align to competence—and autonomy-related concepts such as challenge, performance, and explanation/rationale in *SDT*. Also, students are predicted in *SDT* to feel better about themselves and the process (or worse) through the search and retrieval process, as the ISP suggests. However, the ISP does not provide for a nurturing learning environment and lacks learning design consideration.

Thirdly, Shernoff's (2013) work on *Flow* and engagement reveals that conceptualizing engagement solely through school-based behaviors is inadequate; the psychological student must be acknowledged and nurtured as well. Engagement is an environmental interaction (Shernoff, 2013), and students operate at top efficiency when they approach *Flow* in their activities (Csikszentmihalyi, 1990; Shernoff, 2013; Shernoff, et al., 2014). *Flow* is closely related to social relatedness, competence, and autonomy, the primary element of *SDT*, and the elements of engagement and interest that produce *Flow* can be introduced into the *GID*.

These intersections and cross-pollinations can be integrated into an enhanced, hybrid, *GID*, and interventions can be designed that incorporate interest, *SDT*, and *Flow*. Although this design is intended for a project using science fiction to motivate STEM interest in middle schoolers, it can be adapted for almost any subject. However, since STEM workers now and in the future are currently so vital during the COVID-19 pandemic, I suggest that interventions revolve around STEM subjects following Luokkala's (2014) seven science fiction-Science intersections:

- Nature of space and time (Astronomy, Physics, History of Science, Gravitation).
- Composition of the Universe (Geology, Matter, Light, Energy).
- Machine consciousness (HCI, Artificial Intelligence).
- Aliens (Anatomy, Biology, Zoology).
- The meaning of being human (Scientific Method/Taxonomy, Ethics, Values).
- Solving future problems (Hydrology, Meteorology, Technology).
- What does the future hold? (Computer Science, Genetics, Astronautics) (Luokkala, 2014).

Since some types of school-based research have been halted due to US-based, pandemic-related school closures, actual data may not be available at time of publication. However, the theoretical implications of the described cross-pollinations can be useful by themselves as lesson and learning scaffolds.

Interest Development Theory

Interest can be seen as an information behavior, e.g., the large body of empirical work on choosing a book at the library (Case & Given, 2016). Interest, engagement, and motivation (all 3) are covered in the fields of psychology and educational psychology. Engagement is a result of interest. *Interest* is a predisposition to return to an activity and is triggered either intrinsically or extrinsically; it can be fleeting or long-lasting. It is cognitive and affective. It shares reciprocity with similar motivational variables like goals in *Achievement Goal* and *Goal Complex Theory* (Senko, 2016), and self-efficacy and self-regulation in *Self-Determination Theory* (Ryan & Deci, 2017). Engagement is active involvement in an activity and includes some interest, even if that interest is avoidance-based (e.g., not failing the project). It is cognitive, affective, or behavioral. One can be engaged but not actively interested (e.g., disliking physical education class but participating due to extrinsic controls

like grades and assessment), but one cannot be interested without being engaged. Triggering establishes engagement (Renninger & Hidi, 2011).

Hidi and Renninger's model explains the complex psychological, cognitive, affective, and behavioral elements comprising the development of interest. The interest trajectory spans two levels of extrinsic interest, also called situational or "catch," to two levels of intrinsic interest, also called individual or "hold" (Hidi & Renninger, 2006; Renninger & Hidi, 2016; Renninger & Bachrach, 2015; Harackiewicz, et al., 2000). Extrinsic interest is initiated by a trigger appealing to the natural tendencies of students and empowering them to internalize new objects, concepts, or ideas. The more students personalize them to make them more authentic, the more effective they become as educational scaffolds (Arnone & Reynolds, 2009; Durik & Harackiewicz, 2007). In the early stages of interest, learners may not even know that their interest has been triggered; the power of interest is manifested when behavior changes based on the interest (Renninger & Bachrach, 2015). However, triggered situational interest can also be fleeting (Renninger & Riley, 2013; Renninger & Hidi, 2016); a volcano eruption or worm dissection can be exciting today but forgotten tomorrow (Crouch, et al., 2018). Fostering interest development requires engagement to get past triggered, situational interest (Abbott, 2017). In deeper interest levels, learners often provide their own triggers (Renninger & Bachrach, 2015), and they persevere with tasks related to the task and are increasingly likely to see themselves performing the task as part of their career. Although people tend to have four or five well-developed interests, there is always room for shifting and changing; focus on interest changes regularly (Renninger & Bachrach, 2015; Renninger & Hidi, 2016; Renninger & Riley, 2015). As Fig. 2 suggests, the arc of interest development follows the same general trajectory as the ISP and, hence, the G*uided Inquiry Design* model. As students engage more deeply in their inquiry-based projects, they potentially deepen their interest in the content and subject (DuBoff, 2019).

There are two psychological theories that parallel many of the affective, cognitive, and behavioral elements of the ISP, the *GID*, and the *Four Phases of Interest Development* (Hidi & Renninger, 2006): *Self-Determination Theory* (*SDT*) (Ryan & Deci, 2017) and *Flow* (Csikszentmihalyi, 1990; Shernoff, et al., 2014).

Self-Determination Theory

Self-Determination Theory (*SDT)* offers a psychological lens through which to view the multiple, disparate, sometimes warring impulses and actions that comprise the whole person, defining self-determination through the lens of the continuum of autonomous motivation and controlled motivation (Deci & Ryan, 2008). The goal of instructors and designers is to create learning ecologies in which students, ". . . have identified with an activity's value and ideally will have integrated it into their sense of self" (Deci & Ryan, 2008, p. 182). Autonomous motivation (Deci & Ryan, 2008; Ryan & Deci, 2017) is similar to individual interest (Hidi & Renninger, 2006;

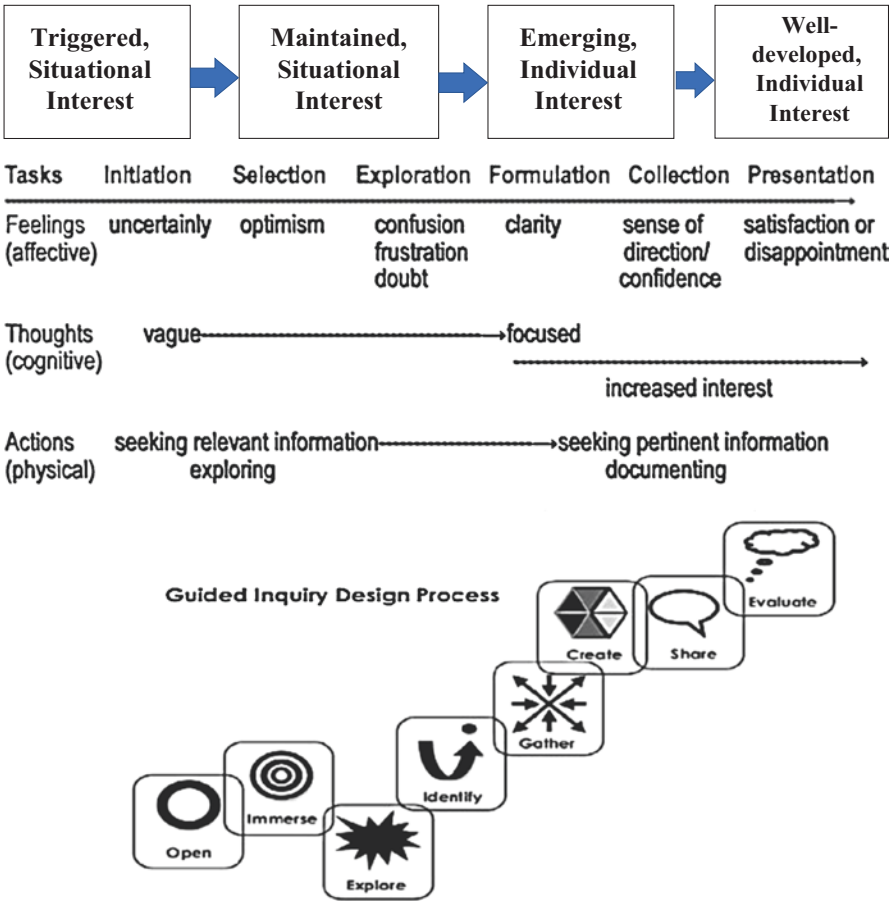

Fig. 2 Model of cross-pollination of Kuhlthau's (1991) *six-stage*, *three-domain ISP* model and Kuhlthau, et al.'s (2015) *GID* with Hidi and Renninger's (2006) *Four Phases of Interest Development*

Renninger & Hidi, 2016): students are self-motivated, have intrinsic interest, and do not require prompting; they are working toward autonomy and intrinsic motivation. Controlled motivation, commonplace in P-12 education, places outside requirements and pressures on students to perform in proscribed ways (Deci & Ryan, 2008). Both intrinsic and controlled motivations promote students to action, even though they may feel differently about each method, e.g., taking a standardized test for 4 days (controlled motivation) versus creating a cool racecar with Legos (intrinsic motivation). Both activities cause action, but students will approach each with a different set of feelings, thoughts, and motivations.

SDT acknowledges the importance of the satisfactions that are associated with autonomy, competence, and social relatedness and asserts an inherent human capacity for reflective, reflexive behavior leading to self-awareness and hence to

self-regulation (Deci & Ryan, 2008; Ryan & Deci, 2017). Human nature is experience-dependent, formed through the decisions to meet or not meet needs and desires, and humans are therefore in constant conflict with their environments. Meeting basic needs leads to a greater likelihood of achieving satisfaction, while thwarting basic needs, whether from extrinsic or intrinsic forces, leads to fragmentation, dysfunction, and vulnerability. Need satisfaction is linked to vitality, while need frustration leads to amotivation. The theory comprises three domains: *autonomy* (Ryan & Deci, 2017), the state in which one feels volitional, congruent, integrated, and self-endorsed, in tune with one's authentic interests and values; *competence* (Ryan & Deci, 2017; Deci & Ryan, 2008), the basic need to feel effectance and mastery; operating in harmony, productively within one's environment; and *social relatedness*, feeling socially connected, belonging, homonomy. This is much like Lave and Wenger's *legitimate peripheral participation* (1991), in which people who share and build communities around an activity move closer to the central, control-wielding group for the activity.

The organismic drive that draws the elements together is dynamic wellness; *SDT* suggests that when one feels the appropriate amount of autonomy, competence, and relatedness that person will flourish, operating with harmony and growth. It is assumed in *SDT* that people want certain levels of wellness attained through affective, behavioral, and cognitive experiences and goals. In fact, *SDT* is the framework current researchers use for conceptualizing goal complexes (e.g., Senko, 2016).

According to *SDT*, learners innately desire to explore their environments in order to grow, learn, and develop. Curricula should address this and promote environments fostering motivation (Haarens, 2020). Successful schools model a tangible enthusiasm for learning and accomplishment, and their students and staff display a genuine desire to want to learn (and teach) well (Deci, et al., 1991). It is this motivational design consideration, not the merging of school and personal space suggested by *GI* and *GID*, that aids students during inquiry in critical thinking, enhanced knowledge acquisition, and most importantly in *SDT*, ". . . a strong sense of personal worth and social responsibility" (Deci, et al., 1991, p. 326). Contrary to the requirements for social construction and collaboration in the *GID*, which not every student likes or desires, *SDT* suggests that simply moving with the crowd without any "buy-in" can be considered amotivational and may even act against personal and social growth (Deci, et al., 1991).

Overall, the value of autonomy and autonomous motivation and/or working toward them is the primary feature in this application. Autonomy is much like well-developed individual interest (Renninger & Hidi, 2016), while controlled activity is more like mandatory performance goal achievement (Senko, 2016). Autonomy is based on intrinsic motivation like personal interests and exciting activities, while control is based on extrinsic motivation like taking corporate-style assessments and performing tasks in specific, predetermined ways with little or no personal input. Autonomy is not independence and vice versa (Ryan & Deci, 2017). Also, one can be autonomous emotionally but controlled behaviorally. The concepts of autonomy and relatedness seem to be opposites in this vein, but they grow and diminish apart from each other.

Students are most creative and productive when they are invested in their own destinies. Additionally, the move toward autonomy through social relatedness and competence is well aligned with both the inquiry-based *GID* and the more general *Four Phases of Interest Development*.

Flow

Flow (Csikszentmihalyi, 1990) is a psychological state in which participants are "in the zone," operating with autonomy and confidence, fully immersed in an activity, oblivious to outside details. It is highlighted by intense concentration, a merging of action and awareness, feelings of control and lack of self-consciousness, and time transformation (Strati, Shernoff, & Kackar-Cam, 2018). *Flow* is a theory of engagement; the state is defined by the fully engaged participant, not necessarily by what brought her there. *Flow* can be utilized, like the ISP and its pedagogical offspring, *GI*, as a roadmap to peak performance. In the classroom, like interest and motivation, engagement is profoundly affected by learning ecologies and working conditions (Shernoff, et al., 2014); students work better when they are offered the affordances that enable successful conditions, such as open participation, free exchange, and appropriate technology.

Flow (Csikszentmihalyi, 1990; Shernoff, et al., 2014) claims its origins in the *autotelic* experience, ". . . a self-contained activity, one that is done not with the expectation of some future benefit, but simply because the doing itself is the reward" (Csikszentmihalyi, 1990, p. 67). The term *exotelic*, conversely, means tasks done for external, controlled reasons. Autonomy and intrinsic motivation (Ryan & Deci, 2017) are represented by autotelic experience, while control and external regulation are represented by exotelic experience. *Flow* is also directly related to engagement; in the initial research leading up to the theory's publication, subjects were asked about their peak experiences, how they felt and performed in optimal environments (Csikszentmihalyi, 1990; Shernoff, et al., 2014). Additionally, *Flow* is associated with *learning goal orientation* theory, the study of the reasons for student engagement in a learning activity (Senko, 2016; Shernoff, et al., 2014). Performance goals in this context represent extrinsic, controlled activities, while mastery goals represent intrinsic, autonomous activities. Mastery goals have shown to be a predictor of Flow state, while performance goals have not (Shernoff, et al., 2014).

In *Guided Inquiry*, performance goals align with the first two stages of interest, triggered, situational interest, and maintained, situational interest, while mastery goals align with the deeper interest levels, emerging, individual interest, and well-developed, individual interest. As students successfully engage in inquiry-based research, the controlled elements of the project can be removed, allowing for increasing autonomy and hence increasing ease of operation.

Implications of the Incorporation of *SDT* and *Flow*

Table 1 (above) suggests the potential influence of interest development on elements of *SDT* and *Flow*. Interest development can be the glue that binds information into students' knowledge bases. The implications should not be underestimated; this is not merely "letting the kids do what they like" and then finding out that 90% of them "like" video games. Interest development has cognitive, affective, and behavioral elements, and these can and should be leveraged into interest in important societal subjects like STEM research and innovation. Science fiction is an excellent choice to generate interest in STEM (DuBoff, 2019), and *Guided Inquiry Design* is an effective way to achieve that goal.

Pedagogy is the bridge between reflective practice, performing an action and then discussing it with others; these experiences become scaffolded knowledge (Shaffer, 2004; Reiser & Tabak, 2014). SF is ideal for a social constructivist environment like that in *GID* because students already create worlds with peers; SF-based and game-based clubs and organizations already thrive due to intercommunication out of school. Young people figured out transmedia (Jenkins, 2006) without adult supervision, and they seem to have amassed and socially constructed quite a bit of knowledge about their favorite television, movie, and/or book series, so interest can increase for some students through the type of multimedia environment of an online *GID* intervention.

The explosive rise in YA dystopian novels and films demonstrates the desirability for a stronger connection between SF and STEM to improve instruction. Appealing to student interests, the choice of a SF series like *The Hunger Games* (Collins, 2008), or uchronic literature like *The Man in the High Castle* (Dick, 1992), an Amazon online television series, is a logical one for adolescents, considering the connections between SF and the Bildungsroman, the "coming-of-age" novel. It is not surprising that many YA series have spawned popular film adaptations. The alienation "bright kids" experience in many fantasy and dystopian, the way characters feel out of place in their given environments, is a very common theme for adolescents, e.g., the characters in Dick's novel are existentially in the wrong reality and living a life that never should have existed; Luke Skywalker discovers his

Table 1 Alignment of interest development, *SDT*, and *Flow*

Interest development stage	*SDT* element	*Flow* element
Triggered, situational	Controlled motivation	Performance goals
Maintained, situational	Controlled motivation begins to evolve as student interest increases	Performance goals begin to evolve as student interest increases
Emerging, individual	Autonomous motivation	Mastery goals
Well-developed, individual	Autonomy	Mastery

special powers and gifts while on a bildungsweg, an educational path to self-formation (Hall, 1988) that often features enlightenment and/or rapid growth and change; e.g., Harry Potter literally wakes up one day to discover he is a wizard; Katniss Everdeen's life course is radically altered in the moment she is chosen to compete in the Hunger Games. It is a unique and singular experience in YA SF to be chosen for greatness, relevant to young adults who feel and live their struggles and triumphs uniquely and singularly.

Buckley (1974) describes the typical Bildungsroman plot as follows: a child gifted in some way is constrained and alienated at home and must leave, and his education in the ways of the world or in the methods of achieving success become equally or more important than school lessons. At the end of the journey, he has been exalted and debased, loved, and loathed; he ultimately loses his adolescence and begins his adult journey, sadder and wiser than when he began. Young SF protagonists are often gifted in some branch of STEM subject; examples in modern SF abound, such as *wunderkind* Andrew "Ender" Wiggin in Card's *Ender's Game* (Card, 2008), helmsman Wesley Crusher on Roddenberry's *Star Trek: The Next Generation* (Stewart et al., 2013), or even Alex Rogan, the video gamer whose mastery of *The Last Starfighter* sends him on a campy, 1980s-hair-filled journey to save the Universe (Betuel, 1985), replicated more recently in the character Wade Watts and the retro-1980s-style *Ready Player One* (Cline, 2011). They are true motivated learners: "They are enthusiastic, focused, and engaged. They are interested in and enjoy what they are doing, they try hard, and they persist over time. Their behavior is self-determined, driven by their own volition rather than external forces" (Garris, Ahlers, & Driskell, 2002, p. 444). It is the drama of the gifted child (Miller, 1990).

Once they find their bildungsweg, YA SF protagonists display well-developed individual interest (Hidi & Renninger, 2006; Renninger & Hidi, 2016) in their task. The need is exemplified by Katniss Everdeen's journey in *The Hunger Games* (Collins, 2008), a novel that invites lessons on genetics, light, sound, flammable and inflammable materials, weaponry, and an actual example of the media's "fake news" through the representation of the corrupt administration of President Snow (Collins, 2008). The "bright kid" is a powerful archetype that should be much more inclusive and appealing than malaise and misery. Although it is assumed ethically that no one wants to put undue pressure on students, expertise is best developed with a model that feels authentic and a personally significant reason to strive for it (Goldman, 2001). Every student has talents that can be built upon using this type of learning that may already appeal to student interests.

Figure 3 (below) demonstrates the addition of *SDT* and *Flow* into the model, providing more design background concerning interest generation and knowledge building, thereby capitalizing on the affective and behavioral elements of student learning behavior. Student interests should be leveraged into project-based artifacts that demonstrate the capacity to affect mastery and expertise, tying in the cognitive element of the learning; the creation process is an excellent crucible in which to grow and refine learning.

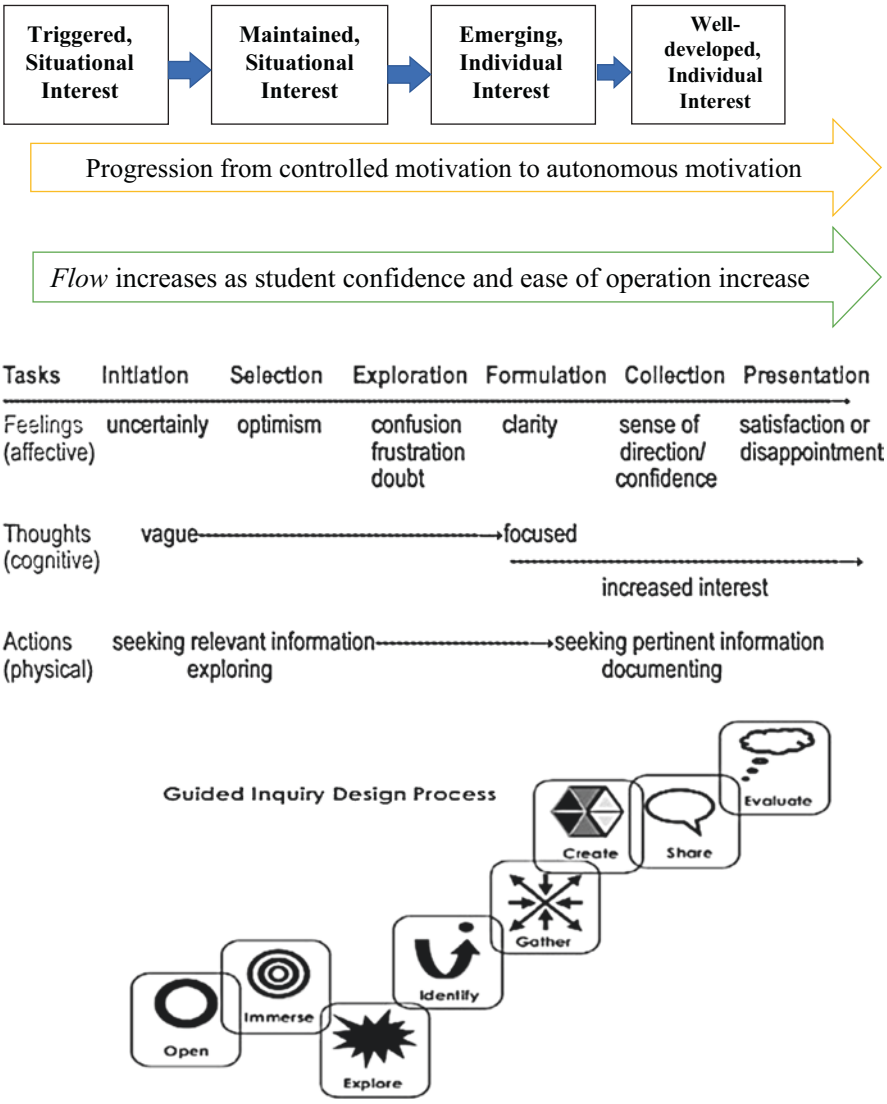

Fig. 3 Model of cross-pollination of Kuhlthau's (1991) *six-stage*, *three-domain ISP* model and Kuhlthau, et al.'s (2015) GID with Hidi and Renninger's (2006) *Four Phases of Interest Development*, Including Trajectories for *SDT* (Ryan & Deci, 2017) and *Flow* (Csikszentmihalyi, 1990; Shernoff, et al., 2014)

In Summary

In 2013, the Next Generation Science Standards (NGSS) Executive Summary assessed the current STEM educational system as a "leaky . . . talent pipeline" (NGSS Lead States, 2013, p.1) and concluded that more interest must be generated to stimulate today's K-12 students: "We need new science standards that stimulate

and build interest in STEM. The current education system can't successfully prepare students for college, careers, and citizenship" (NGSS Lead States, 2013, p. 1). *Guided Inquiry Design* is one effective pedagogy that has great potential to generate STEM interest.

To maximize its effectiveness, the *GID* should contain more entrances for psychological theories like SDT and Flow. Instructional designers entering a *GID*-based unit or advising practitioners about the *Guided Inquiry Design* should give more consideration to the ways in which students interact, respect each other or not, and feel generally good or bad about their tasks and interactions. Interest, motivation, and engagement are key factors in student success or lack thereof. An autonomy-supportive approach to classroom and learning environment management has shown to be an effective method to generate motivation and interest (Cheon, Reeve, & Vansteenkiste, 2020). Instruction in a *GID*-based unit should be autonomy-supportive, funneling students toward intrinsic motivation. Issues such as competition, negativity, and clique-driven inclusion and exclusion can significantly undermine the *GI* process and the collaboration that is required to drive the *GID*. This becomes especially important especially during several phases: the open phase when the learning team is attempting to build an inquiry community composed of all students, the identify phase in which all students in an inquiry circle are supposed to agree upon an inquiry question and topic, and the create and share phases in which students must work together and support each other to produce thoughtful, interesting artifacts and presentations. The environment of a GI-based lesson and/or unit may be compared to an ecosystem, hence the term *learning ecology* (Gundogan, 2016). An ecosystem is healthy when its parts are operating in harmony with each other, and so is a learning environment. The *GID* should include more theoretical background from psychological theories like *Flow* and SDT to address the well-being of the students as they interact with the learning environment. Through ". . . questioning, modeling, listening, and encouraging" (Kuhlthau, et al., 2012, 363), the *GI* learning team can assist students in establishing the life-to-school-topic connections that foster third space in *GI*, and enabling them to feel good doing it, thereby building self-efficacy and confidence.

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