Exploring the Shift in Growth Mindset During Inquiry-Based Learning

A Longitudinal Analysis

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There has been considerable debate about implementing and supporting learners in inquiry-based learning. Although studies have explored trends in cognitive learning outcomes over time, less is known about the socio-emotional aspect as learners engage in complex problem-solving. This study conducts a longitudinal analysis within a middle school (Grades 6-8) to understand shifts in growth mindset over a semester as learners engage in inquiry-based learning. Results determined an interaction effect regarding time *and grade level as learners engage in inquiry-based learning, with statistically significant growth mindset improvements for first-year students. Implications for theory and practice are discussed, especially as they relate to the socio-emotional transition to inquiry-based learning.*

Introduction

Modern theorists suggest that educators should implement instructional strategies that support problem-solving as a way to foster higher-order learning (de Jong et al., 2023; Koehler & Vilarinho-Pereira, 2021). Inquiry-based learning strategies often implement some form of case at the center of the learning experience, which affords agency and requires learners to engage in a more self-directed approach during problem-solving. The inquiry-based learning strategy requires learners operate in two primary phases as they navigate the contextual nature of the case: problem representation and solution generation. The former requires that learners identify the latent and salient variables that are central to the case; the latter asks learners to identify ways to solve the complex problem. In doing so, learners are also afforded opportunities to engage in an array of problem-solving activities, such as information-seeking, question generation, causal reasoning, decision-making, and others as they develop solutions to the ill-structured problem (Tawfik & Kolodner, 2016).

To date, several studies have focused on the cognitive aspect of problem-solving during inquiry-based learning, which has enhanced the field's understanding of scaffolding, self-regulated learning, and others (Kim et al., 2019). However, inquiry-based learning includes other aspects of the learning experience, such as the socio-emotional experience of the learner. Indeed, the ill-structured nature of the case may consist of enhanced complexities and challenges, so it follows that socio-emotional components are impacted during problem-solving (Sulistiyo & Wijaya, 2020). For example, educators suggest that cases are more engaging and motivating compared to didactic forms of instruction devoid of context (Zhang & Ma, 2023). Moreover, the complex nature of the case often includes impasses and failure during problem-solving, which may impact self-efficacy (Tawfik et al., 2020). Another related affective component includes what theorists call the "growth mindset" of a learner (Dweck & Yeager, 2019). Whereas a fixed mindset describes a belief that intelligence is inherited and can not be developed, a growth mindset describes learners' belief that intelligence is malleable given (a) adequate effort and (b) refinement of learning strategy. Studies suggest a growth mindset is beneficial for students, regardless of the students' socioeconomic status, gender, race, or current academic ability (Yeager & Dweck, 2020). Additional literature suggests that a growth mindset development could reduce academic achievement gaps as students with a growth mindset are more resilient and open to making mistakes (Stohlmann, 2022).

A growth mindset may have important implications for the complex problem-solving encountered in inquiry-based learning. Related research highlights how problem-solving is an iterative process, which suggests that learners rarely resolve a case in a single pass (Frerejean et al., 2021). Instead, learners often encounter challenges and failure as they navigate variables embedded within an ill-structured case (Holmes et al., 2014). One might thus argue a growth mindset approach is needed as learners engage in the iterative problem-solving inherent within inquiry-based learning. However, extant studies of growth mindset are often focused on specific interventions designed to shift a learner's perspective (e.g., - an online module) rather than exploring the potential variable trajectory of growth mindset during inquiry-based learning (Dweck & Yeager, 2019). It is therefore important to further explore this empirical gap, especially as many learning standards now emphasize complex problem-solving.

The manuscript first revisits the literature associated with problem-solving and how case-based reasoning (CBR) theory describes the rationale for inquiry-based learning as an instructional strategy. Following this section, the article provides an overview of the literature associated with a growth mindset, including the emerging literature on applied learning interventions through technology. The manuscript will then address the aforementioned gap as it explores the variability of growth mindset as learners engage in inquiry-based learning over time.

Literature Review

Case-Based Reasoning Theory and Problem-Solving

Traditional educational approaches often entail a didactic approach whereby educators disseminate contextualized information in some form of lecture-based approach. In recent decades, theorists suggest that learners should instead be taught through an inquiry-based learning strategy, which allows learners to problem-solve using ill-structured cases that are germane to the issues found in domain practice (Glazewski & Ertmer, 2020; Jonassen, 1997). Beyond just the content, the roles of the learner and educator also shift. Learners adopt an active (Yannier et al., 2021) approach with peers as they share ideas about the relevant variables within the case, engage in meaning-making, and negotiate new knowledge (Ba et al., 2023). Educators facilitate instruction through scaffolding and post-hoc reflection (Ertmer & Koehler, 2018). Although varying opinions exist as to its efficacy (Zhang & Cobern, 2020), research suggests properly scaffolding students in inquiry-based learning outperforms lecture-based studies on a variety of learning outcomes, including conceptual knowledge (Minner et al., 2010), information seeking, and collaborative problem-solving (de Jong et al., 2023)

One of the ways to understand the benefits of inquiry-based learning is through the lens of case-based reasoning (CBR) theory, which argues that learning is largely experiential and can be leveraged to solve future problems (Schank, 1999; Tawfik & Kolodner, 2016). When individuals encounter a case, they will attempt to resolve the issue through retrieval of a related experience. At this stage, how learners index (e.g., - label or 'tag') a case is critical and serves as the primary mechanism for the retrieval process from one's internal case library. If the individual deems the case relevant based on similarity assessment, they will then reuse the case to understand its scope and derive a potential solution. If they do not see the solution sufficing the issue, they will revise their understanding of the situation and retain the case with the appropriate indices (Shokouhi et al., 2014; Xiong, 2011).

CBR theory thus has important implications for problem-solving in terms of (a) importance of strategies which use a case as central to the problem-solving experience and (b) how expertise grows as learners develop a case library (Tawfik & Kolodner, 2016). In terms of the former, many instructional strategies, such as inquiry-based learning, pose an ill-structured case for learners to solve during class time, which serves as the catalyst for knowledge construction as learners understand the salient and latent variables embedded within the case. As the learners progress in their education, they are able to engage in the CBR cycle (retrieve, reuse, revise, retain) as they draw from a rich set of experiences in the form of a case library when they encounter additional problem-solving settings. Over time, educators argue this repository of experiences better prepares individuals for the complex problems often encountered in domain practice (Belland & Kim, 2021; Jonassen & Hung, 2008).

Research on Growth Mindset

An essential component of inquiry-based instruction is how learners develop agency and engage in self-directed learning. This entails many important concepts, including metacognitive strategies, self-efficacy, and others during problem-solving. An emerging area within education research also included the types of mindsets as learners pursue their goals. Theorists argue that learners' mindset falls along a continuum of growth and fixed mindsets, which are important as learners ascertain outcomes and subsequent efforts (Dweck & Yeager, 2019). A fixed mindset believes that one's ability is innate and often dictated by external attributes, such as predisposed ability, grades, or the perceptions of peers. Those with a fixed mindset frequently exhibit a performance-oriented perspective, so they expect learning to operate efficiently and linearly if they believe they are innately strong at a particular topic. Rather than developing deep learning, one's ability is often focused on summative achievement and outperforming peers (Savvides & Bond, 2021) instead of skill mastery (Xu et al., 2021). Additional studies detail how a fixed mindset is correlated with how learners attribute failure to personal characteristics, performance-avoidance goals, and beliefs about effort (Dweck & Yeager, 2019). This not only impacts school performance but also negatively impacts the level of challenge they might pursue during their learning experiences.

The predetermined approach described above contrasts with a growth mindset which asserts that one's ability is malleable and can be improved with appropriate effort. As learners exhibit effort and persistence, they adopt a goal achievement and a master-oriented approach during their learning which serves as the foundation for motivation, behavior, and learning outcomes (Burnette et al., 2023). This also impacts how learners perceive the value of encountered failure and their persistence during instruction (Moser et al., 2011; Rege et al., 2021). Campbell et al. (2020) argue that other characteristics of a growth mindset are that individuals are more likely to embrace challenges, exhibit individual persistence, value praise for effort, aspire to the successes of others, and engage in goal-setting. Indeed, large-scale studies have reported on the effectiveness of growth mindset interventions when learners are adequately supported (Tipton et al., 2023)

Research on Growth Mindset and Educational Technology

Since Dweck (2006) published her seminal work, educational researchers have increasingly focused on implementing additional supports to facilitate the development of learners' growth mindset, with a consistent finding that a growth mindset requires consistent support throughout the learning experience (Campbell et al., 2021). At the same time, a growth mindset requires myriad student supports, including teachers and other learning resources (Yeager et al., 2019). In many respects, the interactive nature of technology and learning-informed design can serve as a resource for teachers who wish to support a growth mindset within students. For example, technology can support the socio-emotional component as it provides online strategies for applying and adopting tenets of a growth mindset. Alternatively, technology can serve as an interactive tutor that provides just-in-time support for iterative refinement of knowledge, reinforcing key aspects of a growth mindset within the student (Campbell et al., 2021). Furthermore, learning technologies can be designed to provide automated and tailored feedback that encourages learners to adopt a mindset at strategic times during problem-solving (Yeh et al., 2023). Other studies have indicated positive results on developing a growth mindset when implementing various learning technologies such as gamified learning, multimedia videos, or online modules containing growth mindset exercises (Inchamnan & Chomsuan, 2020; Shirazi & Rahimi, 2023; van de Sande & Reiser, 2021). Collectively, these studies suggest technology can be leveraged to support knowledge trajectory and thus facilitate growth mindset development as they appropriately progress during learning (Pernía-Espinoza et al., 2017; Tseng et al., 2020; Xu et al., 2021).

Research Questions

Research on growth mindset has shown to be replicable; however, studies need to be more comprehensive about the instructional strategies that teachers can implement to engender a growth mindset in students (Yeager & Dweck, 2020). Indeed, a growth mindset aligns with the iterative problem-solving component and encounters the complexity found within cases assigned during inquiry-based learning. Despite its importance, a systematic review by Campbell et al. (2021) found a lack of repeated measures of growth mindset studies, so they call for "longitudinal studies on growth mindset interventions to track possible benefits that may be missed in shorter studies. Shifting beliefs is often a slow process and most of the included studies reported on results gathered over a semester or a year" (p. 515). As such, less is known about the temporal aspect, especially regarding a growth mindset as learners are regularly exposed to complex problem-solving inherent within inquiry-based learning. One might assume a linear growth approach as students engage with the cases and construct their knowledge. Alternatively, students might exhibit shifts in their growth mindset as they encounter challenges and errors as part of inquiry-based learning. Researchers and educators should further seek to understand how a learner's growth mindset adapts over time during problem-solving. Given this gap, we proffer the following research questions:

1. To what degree does growth mindset change over the course of a semester as K-12 learners engage in inquiry-based learning?
2. Based on grade level, to what degree does growth mindset change over the course of a semester as K-12 learners engage in inquiry-based learning?

Methodology

Participants and Procedure

Participants (N = 53) consisted of urban middle school students (Grades 6-8) enrolled in a public school in a metropolitan city in the Southeastern portion of the United States. The school comprises 265 students, with approximately 18 students per class size. A unique aspect is this public school predominately employs inquiry-based learning as the primary strategy and curriculum for their learning, which requires learners to collaborate with peers to solve assigned cases as teachers serve as facilitators of the groups. Learners often work in groups of 3-5 individuals, and class time is allotted for groups to work with their peers to develop solutions for the assigned cases. Across the school, students completed over 60 inquiry-based learning projects as part of the academic year.

Upon approval by the Institutional Review Board (IRB), participants were sent consent materials to inform them of the study. Data included survey questions digitally administered to the students. Specifically, data was collected on the final day of each month for the Fall semester: the final days of September, October, and November. Participants were sent a Qualtrics survey about their growth mindset perceptions as they engaged in the digital cases assigned during inquiry-based learning. Participants were given one week to complete each survey, with one reminder email at the end of the week. In addition to working with the school administration, additional approval was received by the parental board prior to administering the surveys to students. Given that participants were under the age of 18, any responses were removed if there was not dual approval by the student and their guardian.

Instrument

Growth mindset was evaluated using three questions derived from Dweck (1995) and colleagues. Students were presented with the following three questions: (a) “You have a certain amount of intelligence, and you can’t really do much to change it”; (b) “Your intelligence is something about you that you can’t change very much”; and (c) “You can learn new things, but you can’t really change your basic intelligence.” Students indicated their level of agreement with each response using a 6-point Likert scale (1: “strongly disagree” to 6: “strongly agree”). The same three questions were presented at each round. In line with prior studies of growth mindset (Lurie et al., 2023; Malespina et al., 2022), the three scores were then developed into a composite score, with a total possible score of 18. Higher scores represented a more fixed mindset, whereas lower scores indicated a more growth-oriented mindset. Internal consistency reliability for the total scores was good for all three rounds (Round 1: $\alpha = .83$; Round 2: $\alpha = .90$; Round 3: $\alpha = .92$).

Analysis

To test the effect of time on growth mindset (Research Question 1), researchers completed a repeated-measures analysis of variance (ANOVA) of the student responses across the three testing occasions. As stated above, a calculated sum score of the three questions served as the dependent variable, allowing the research team to explore whether a student's composite score changed from round to round. To ensure the appropriateness of the test, we evaluated the assumptions of both normally distributed residuals and sphericity. As sphericity was violated ($p = .039$, $\varepsilon = .91$), we report the Huynh-Feldt corrected test values. This correction adjusts for Type I error and is recommended when $\varepsilon > .60$ (Blanca et al., 2023).

To answer Research Question 2, we ran a mixed-design ANOVA to determine whether the effect of time on growth mindset varied by grade level. For this analysis, we combined seventh and eighth-grade students into a single group. We did this to compare students who were familiar with the school's old method of instruction and who had received prior instruction at the school (seventh and eighth-grade students) to those who were new to the school (sixth-grade students). For the mixed-design ANOVA, we followed the same procedures as in the repeated-measures ANOVA. Equality of variance was violated for the third round ($p <.001$). However, the analysis should be robust due to the relatively equal sample sizes ($n = 22$; $n = 23$, respectively (Stevens, 2007). Sphericity was again violated ($p = .008$, $\varepsilon = .90$), so we again report the Huynh-Feldt corrected values. After conducting the mixed-design ANOVA, we explored the Bonferroni-corrected simple main effects of time for grade-level groups, although some researchers suggest caution in interpreting post-hoc tests when sphericity is violated (Howell, 2002).

Results

In all, 45 students provided complete data across all rounds of the analysis. Mean total scores ranged from 3.00 to 18.00. Pearson correlations between scores were all positive ($r_{Time\ 1,\ Time\ 2} = .64$, $r_{Time\ 1,\ Time\ 3} = .65$, $r_{Time\ 2,\ Time\ 3} = .83$). Table 1 shows the mean sum scores of the three questions for each round and for grade level groups. To answer Research Question 1, a repeated-measures ANOVA was run to determine whether time had an effect on students' belief about growth mindset during problem-solving, as measured by the sum scores of the three instrument items. Results of the analysis suggested that time alone did not significantly affect the mean scores.

Table 1

Descriptive statistics for growth mindset total scores across the three rounds

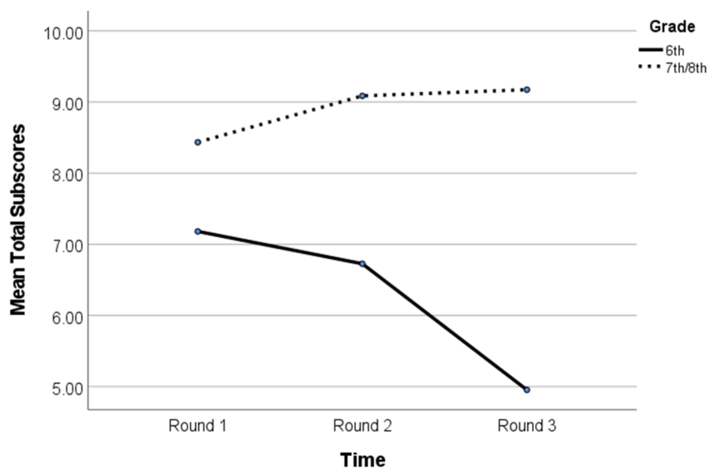
	Total Sample(n = 45)		**Sixth Grade(n = 22)**		**Seventh/Eighth Grade(n = 23)**	
	M	SD	M	SD	M	SD
Round 1 (September)	7.82	4.10	7.18	3.86	8.43	4.31

Round 2 (October)	7.93	4.63	6.72	4.15	9.09	4.85
Round 3 (November)	7.11	4.43	4.96	2.73	9.17	4.79

To answer Research Question 2, the mixed-design ANOVA was run to further explore any changes in growth-mindset scores when taking into account grade level. The results were similar regarding the main effect for time. That is, time alone did not have a significant main effect on mean responses. However, the main effect for grade was significant (F1, 43 = 8.34, p = .022, ηp2 = .12). Students in sixth-grade who had only experienced the school's inquiry-based learning scored on average 2.61 points lower (e.g., reflective of a more growth-oriented mindset) than their peers who had been at the school prior to its implementation (seventh- and eighth-grade students), which was a large effect. The interaction effect more clearly explains this relationship. Sixth-grade student scores decreased significantly in relation to their upper-grade counterparts (Figure 1).

Figure 1

Repeated measures of student growth mindset mean scores during inquiry-based learning



However, given that the multiple comparisons may not be fully protected by the Huynh-Feldt, the grade-level by time interaction had a large effect on the total scores (F1, 43 = 8.34, p = .006, ηp2 = .16). When exploring the simple effects for time on Grade 6, the decrease in scores occurred between the second and third administration ($M_{difference}$ = -1.77, p .012, CI95: -0.32, -3.23; Table 2). However, given that the Huynh-Feldt procedure may not fully protect the multiple comparisons, caution must be used in interpreting this result.

Table 2

Simple effect pairwise comparisons of mean difference sum scores for Sixth Grade Students

	Round 1	Round 2	Round 3
Round 1 (September, M = 7.18)	-	-.455	-2.23*
Round 2 (October, M = 6.73)		-	-1.77*
Round 3 (November, M = 4.96)			-

Note. p < .05

Discussion

Modern theorists and educators suggest students should be provided opportunities to engage in problem-solving as part of the learning experience (Jonassen & Hung, 2008; Kim et al., 2018). This is often applied through inquiry-based learning, whereby teachers facilitate learning as learners solve complex and ill-structured cases with their peers (Ertmer & Koehler, 2018). When learners are given proper support, research suggests higher-order learning outcomes, such as decision-making (Tawfik & Gatewood, 2022), causal reasoning (Shin & Jeong, 2021), and argumentation (Belland & Kim, 2021) are improved. While some inquiry-based learning studies have focused on affective measures related to self-efficacy and motivation (Fielding-Wells et al., 2017), research is limited on the other socioemotional outcomes of inquiry-based learning. Moreover, many studies within inquiry-based learning are focused on a single case study or intervention (e.g., scaffolding comparison), which may limit understanding of inquiry-based learning as a more holistic and sustained instructional method (de Jong et al., 2023; Verma et al., 2023). To date, there have been some studies which have explored inquiry-based learning and growth mindset, especially within the STEM context (Boaler et al., 2022; Campbell et al., 2021; Vongkulluksn et al., 2021). Despite the temporal aspect of growth mindset, a recent systematic review found a considerable gap: "none of the included studies investigated the long-term effects of the growth mindset interventions" (Campbell et al., 2021, p. 515). This research addresses this gap and extends prior work inquiry-based learning as it explores aspects of growth mindset across the curriculum over time and between different grade levels.

Although there was no effect when learners were aggregated, the current data suggests an interaction effect regarding time and grade level as learners engage in problem-solving. Specifically, sixth-graders appeared to increase their growth mindset in the first semester of an inquiry-based learning approach. There may be multiple interpretations for this finding. First, this finding may speak to related research regarding the transition to inquiry-based learning regarding learner autonomy and specific skills learners must develop for this instructional strategy. In contrast to many information dissemination approaches (e.g lecture) found within many elementary settings, inquiry-based learning requires learners take ownership of the material as teachers take on a facilitator role (Adler & Sarsour, 2023). Learners must also develop skill such as information-seeking, decision-making, and causal reasoning which are less prevalent in the lecture format found within didactic instruction (Glazewski & Hmelo-Silver, 2018). Moreover, the strategy also requires students manage project milestones, peer dynamics, and other aspects of learning. There has been considerable debate about the novice's ability to transition to inquiry-based learning (de Jong et al., 2023; Hmelo-Silver et al., 2007; Zhang et al., 2022). Despite criticism that inquiry-based learning is problematic for novice instruction (Zhang et al., 2022), the evidence suggests first-year learners were able to transition well to the socio-emotional component of the problem-solving approach over time, as measured by the increased growth mindset.

The results have theoretical and practical implications for adopting a growth mindset during problem-solving. Regarding the former, one should not assume a growth mindset is similar or static across grade levels, especially when it is novel to the student and represents a shift in their prior approach. It follows that learners may require specific affective interventions which target the affective domain of learning depending on their introduction to problem-solving. Thus far, much of the discourse has focused on how to support cognitive aspects during inquiry-based learning. It may be additional support is needed to support a growth mindset as learners engage in complex problem-solving cases. For example, a learning technology could embed adaptive prompts when failure is more likely to occur, such as when learners implement a solution and must iterate based on their desired outcomes. Another example may be encouraging a growth mindset during ongoing facilitation through the case or reflection sessions that occur post hoc. To date, studies on reflection are often focused on considering learners' prior problem-solving strategies, with little guidance about how to support the affective side of problem-solving (Turner et al., 2023). This may be especially true for a growth mindset, especially since it is closely related to constructs such as self-efficacy and learning from failure that often occur during inquiry-based learning.

Limitations and Future Research

While the study provides additional information on the role of a growth mindset during inquiry-based learning, multiple ways exist to build from the current research and substantiate its findings. The research explores the temporal aspect of growth mindset over a semester, so it follows to conduct further studies about any shifts in growth mindset over a longer period (e.g., a full academic year). Studies which explored change over a more extended period with a larger sample could also support a more robust analysis of the phenomenon than that provided in this study. In the current study, the inquiry-based process was novel to many sixth-graders at the time of their survey completion. The results may not be exclusive to inquiry-based learning but might also include other facets such as new teachers, peers, and learning resources (e.g., library, etc.). Additional exposure to cases might follow different growth mindset patterns, especially for novices as they become more familiar with inquiry-based learning, self-directed learning strategies, and other students within their educational contexts.

Another related study could explore the relationship between a growth mindset and the problem-type encountered during inquiry-based learning. For example, Jonassen and Hung (2008) suggest there are various problem-types inherent within specific domains, such as design problems in engineering or ethical dilemmas posed within many social studies contexts. The authors further argue these domain-specific challenges may require different rules to dictate problem-solving cycles, which would likely impact their growth mindset. For example, many STEM problems may place more of an emphasis on engineering design and iterations when a solution fails. In contrast, problems in the social sciences might focus on the articulation of alternative perspectives. Additional research could explore how these distinctions across domains and problem-types might further support educators who wish to engender a growth mindset during inquiry-based learning.

Future studies could also examine alternative measures and methodologies, especially from various stakeholders. In the current research, students were asked to share their growth mindset via a survey, while additional insight might be gleaned from a qualitative approach. Indeed, a growth mindset is a complex construct that includes how learners understand a problem, engage in self-directed learning, encounter failure, and others. A qualitative approach might provide additional insight into how learners encounter and manage these dynamics over time. Because the inquiry-based model includes changes for the teachers, the study could explore a mixed approach that considers quantitative or qualitative approaches from other stakeholders such as teachers. A more holistic understanding of the learning experience can better facilitate and foster a growth mindset within problem-solving settings.

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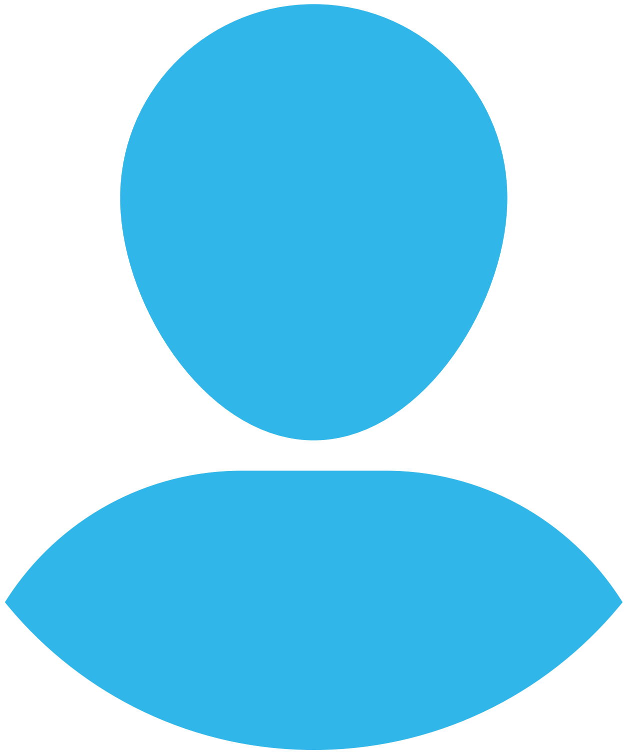

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