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Informing Recommended Makerspace Outcomes through Linguistic Analytics

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Abstract: An after-school maker club collected student reflections on makerspace projects in different formats over two years: private written reflections captured in the 3D GameLab gamification platform and video-recorded reflections posted in the more social FlipGrid platform. Club mentors selected these documentation platforms on the basis of their motivational affordances thought to encourage club members to document their work. Transcribed documentation was analyzed using Linguistic Inquiry Word Count (LIWC) software to generate linguistic profiles for comparison. Differences between written and video-recorded documentation suggest: private, written documentation is more likely to capture evidence of cognitive processing and achievement- or risk-oriented drives, but may be more negative in tone; semi-public, video documentation is more likely to capture evidence of social affiliation-oriented drives and may be more positive in tone. Future research should investigate linguistic impacts given merged approaches of reflective writing for social spaces, or reflective writing in social groups.

STEM Innovation Through Making

A makerspace is typically a physical learning environment that takes advantage of shared tools, resources, and expertise to promote interest-driven creation and play with the support of a community. The maker movement has considerable historical antecedents in Montessori schools, Dewey's Progressive Education movement, Piaget's constructivist learning, Papert's constructionist learning, and Kolb's experiential learning (Hira, Joslyn, & Hynes, 2014; Sheridan et al., 2014). The increasing availability of inexpensive and open source tools for consumer making along with forums for sharing and remixing makes has increased makerspaces in communities, homes, and recently schools (Hagel, Brown, & Kulasooriya, 2014).

A college of education and public school in the southeastern United States received a science enrichment grant to establish an informal, after-school maker club (2016-19). This project targets three goals: 1) develop students' problem-solving skills associated with computational thinking through interest-driven inquiry; 2) develop students' leadership skills through personally relevant quests, maker community collaborations, and opportunities to lead making events; and 3) develop students' understanding and appreciation of STEM college and career paths. Students work in three units aligned to the state's math/science curriculum in grades 6-10: circuitry (e.g., paper circuits, soft circuits, LittleBits), programmed robotics (e.g., Scratch coding, Hummingbird and Sphero, K'Nex control kits, MicroBits), and fabrication (e.g., paper crafts, MakeDo construction, 3D pens and printers). The club meets in a science classroom one afternoon per week where maker equipment and materials are stored in three mobile carts.

Two Approaches to Assessing Learning in the Informal Makerspace

Peppler, Keune, Xia, and Chang (2018) note that assessment practice in makerspaces is "ahead of research" with "researchers not providing a firm answer on how makerspace learning can be measured" (p. 11). This study tests two approaches to student self-reflections on learning in makerspaces, each with suggested motivational affordances: private, written documentation between a student and mentor captured in a gamification platform (year one, case one); and semi-public, video-based documentation captured in a social media space (year two, case two). To encourage and capture documentation in year one (2016-17), we populated more than 40 quests from the aforementioned project areas into the 3D GameLab (Rezzly) gamification platform and assigned each student an account. Students were asked to complete quests in each project area to earn points, levels, and badges consistent with gamification principles. A public player card and leader board showed students who had completed which quests and who had earned the most points or badges. Students documented quest completion by answering prompted questions in writing and uploading one or more photos of their completed quest for verification by club mentors.

Gamification systems are assumed to be intrinsically motivating on the basis of applying game mechanics that people associate with fun to learning. Critics, however, argue that "reward-based" gamification systems with points and badges are extrinsically motivating like letter grades, advocating instead for "meaningful" gamification that uses non-point game elements (challenges, narratives, play, choice) to encourage personal connections to material (Becker & Nicholson, 2016). Students did not document as many quests as desired in this platform, and reflections were quite brief. Students commented that the platform did not seem like a game, just "more work," suggesting it was perceived as extrinsically motivating. To address these perceptions of documentation platform, in year two (2017-18) we opted to test the motivational affordances of a more open, social platform for capturing reflections. FlipGrid is a Web-based tool that prompts and collects video responses from any digital device with a camera (e.g., laptop, smart phone). In this platform, students again responded to prompted questions, but this time using selfie-style videos in which they held up, demonstrated, and talked about their work. Social media platforms have received recent attention as a tool to engage learners and support identity development through articulation and community negotiation (Craig-Hare, Rowland, Ault, & Ellis, 2017; Pinkard, Erete, Martin, and McKinney de Royston, 2017).

Assessment of informal learning is a known challenge given divergent social-cognitive outcomes one could study (see, for example, Lemke, Lecusay, Cole, & Michalchik, 2015) and the restrictive nature of tapping into developing ideas, questioning, and changing interests (Brody, Bangert, & Dillon, 2007). Lemke et al. (2015) found that effective documentation and assessment of informal learning activities should not only include content knowledge but also social, emotional, and developmental outcomes. The Tinkering Learning Dimensions Framework (TLDF) (Bevan, Gutwill, Petrich, & Wilkinson, 2014) categorizes learning outcomes in making into four dimensions: 1) Engagement (e.g., learners "try something over and over" or "show emotions such as joy, pride, or disappointment"); 2) Initiative and Intentionality (e.g., learners develop strategies and persist in their goals); 3) Social Scaffolding (e.g., learners "offer ideas and approaches" or "innovate and remix by using or modifying others' ideas"); and 4) Development of Understanding (e.g., "learners offer or refine explanations" or "connect to prior knowledge") (p. 8).

To gain insight into these TLDF social-cognitive outcomes and their presence or absence in our makerspace, this study employed Linguistic Inquiry Word Count (LIWC) data mining software. Specifically, we analyzed written and video-recorded transcripts for evidence of specific linguistic variables (psychological constructs) thought to be aligned with TLDF dimensions. We looked at LIWC affect variables thought to inform engagement, cognitive process variables thought to inform development of understanding, and drive variables thought to inform both initiative and intentionality and social scaffolding.

Methods

The exploratory case study was selected as an appropriate research design to study our changing documentation conditions, to provide insight into the phenomenon of prompted student reflections in a physical makerspace, and to inform future research. Linguistic profiles of written and video-recorded documentation were generated through analytics to represent these two unique cases. Profiles in cases were subsequently compared through cross-case methods to reveal differences and to generate hypotheses regarding relative affordances of each approach to be confirmed in future research. The following research question was addressed: 1. What psychological constructs are reflected in student documentation and how do these vary by case (written versus video-recorded)? The maker club in this study serves grades 6-10 girls (ages ~11-15) at a public, all-girls school in an urban city in the southeastern United States. In 2016-17 (year one, case one), 34 students participated with a mean attendance of 15.3 out of 25 scheduled meetings (average 30.7 contact hours). In 2017-18 (year two, case two), 37 students participated with a mean attendance of 16 out of 27 scheduled meetings (average 31.9 contact hours).

In both documentation platforms, students were prompted to answer questions written by club mentors to prompt computational thinking: 1) What worked and did not work so well in completing your project (decomposition, pattern recognition)? 2) What was the most challenging part of this project and how did you overcome that challenge (decomposition, evaluation)? and 3) How would you change your process the next time (evaluation, abstraction, algorithmic thinking)? The procedures resulted in 164 written documentations in year one and 74 video documentations in year two (n=238) (see Table 1). Particular projects documented in a given year differed with three exceptions (paper craft, paper circuits, soft circuits). Comparisons were made between written and video documentation for the overall data set and for these three matched project sets to help verify the overall comparison.

	2016-17 (Y1)	*2017-18 (Y2)*
3D Pen/Printing (Fabrication)	19	0
Paper Craft (Foldify, Masks, Coasters) (Fabrication)	25	22
Sewing (Fabrication)	3	0
LittleBits (Circuitry)	34	0
Snap Circuits (Circuitry)	15	0
Paper Circuits (Circuitry)	27	21
Soft Circuits (Circuitry)	24	13
Spin Bots (Circuitry)	0	0
Coding Cards (Programming, Robotics)	5	15
Hummingbird (Programming, Robotics)	12	2
Sphero (Programming, Robotics)	0	1

Table 1: Number of Specific Projects Documented Per Year

To prepare data for analysis, video documentation was transcribed. Written and video documentation were added to a common spreadsheet with categorical codes to support comparisons (i.e., documentation type, project category, project type). To probe for any differences between written and video-based documentation, each text was separately analyzed by the 2015 edition of the Linguistic Inquiry Word Count (LIWC) text analysis software (Pennebaker, Boyd, Jordan, & Blackburn, 2015). LIWC outputs 90 linguistic variables to represent each text, including simple linguistic variables (e.g., word count, words greater than six letters, parts of speech), summary language variables (e.g., authenticity, emotional tone), evidence of psychological constructs (e.g., affect, cognition, drives), evidence of personal concerns (e.g., home, work), and more (Pennebaker et al., 2015). After using LIWC to output variables, scores were imported into SPSS where independent samples t-tests were ran between four data sets: written compared to video across the entire data set, and written compared to video across three matched project sets.

Findings and Interpretations

The mean percent of words in written and video-recorded documentation of an affect type (e.g., happy, cried) is shown in Table 2, and in general was very low suggesting affect is not commonly represented in maker project documentation (e.g., a mean of 3.56% of the words across all written documentation were of a "positive emotion" type as matched to the LIWC dictionary). The percent of overall affect words was significantly higher in written documentation for the overall data set and for one matched data set (paper craft projects). The percent of negative emotion words (e.g., hurt, ugly, nasty) was significantly higher in written documentation for the overall data set and for all three matched data sets. The percent of positive emotion words (e.g., love, nice, sweet) was significantly higher in video documentation for one matched data set (soft circuit projects).

Written documentation may be the forum in which students are most likely to express affect, particularly negative emotions, although affect language overall tends to be low in maker project documentation. In this project, only the student and club mentor were able to view 3D GameLab written documentation (private) compared to the FlipGrid video platform (semi-public), so students may be more likely to air grievances or report problems in private writing and more likely to express positive emotion in public video.

	Documentation Source								
	Written (GameLab)			Video (FlipGrid)					
	M	*SD*	n	*M*	*SD*	n	*t*	*p*	ES
Affect	5.50	3.27	164	4.67	2.17	74	2.32	.02	.30
Positive Emotion	3.56	2.96	164	4.12	1.95	74	-1.74	.08	-.22
Negative Emotion	1.93	1.43	164	.53	.67	74	10.29	.000	1.25

*Equal variances not assumed; more conservative values reported

Table 2. Independent Samples T-Test Comparing Mean Percentage of Words in Written Vs. Video-Recorded Documentation that Reflected Affect, Across All Project Assessments (n=238)

The mean percent of words from written and video documentation that fell into cognitive processing categories is shown in Table 3. Overall, 16.9% and 15.3% of the words found in written and video-recorded documentation respectively reflected cognitive processing words from the LIWC dictionaries. The mean percent of overall cognitive processing words (e.g., cause, know), discrepancy words (e.g., should, would), and certainty words (e.g., always, never) was significantly higher for written reflections in the overall data set and one additional matched data set each.

Students exhibited some characteristics of cognition in their maker project documentation. That more overall cognitive processing words may be elicited from written documentation, may suggest written forums are preferable for eliciting academic talk. The higher levels of discrepancy in written documentation may be related to the aforementioned negativity found in this forum and one's willingness to articulate in a private space where things have gone wrong in a maker project (e.g., "it should have done this…"). The higher certainty variable in written documentation could reflect students trying to convince the instructor to approve their work (i.e., "I learned a lot, I have no questions, I wouldn't do anything differently…"). In contrast, video documentation was not approved in a system, so students may have been more willing to express uncertainty, not fearing the instructor may "return" their work.

	Documentation Source								
	Written (GameLab)			Video (FlipGrid)					
	M	*SD*	n	*M*	*SD*	n	*t*	*p*	ES
Cognitive Processes	16.87	5.21	164	15.32	4.81	74	2.17	.03	.31
Insight	2.07	2.21	164	2.00	1.39	74	*.31	.76	.04
Cause	3.70	2.55	164	3.97	1.87	74	*-.93	.35	-.12
Discrepancy	3.03	1.87	164	2.03	1.11	74	*5.14	.000	.65
Tentativeness	3.14	2.34	164	3.52	1.62	74	*-1.47	.14	-.19
Certainty	1.77	1.69	164	1.07	1.18	74	*3.68	.000	.48
Differentiation	3.98	2.53	164	3.47	1.76	74	*1.81	.07	.23

*Equal variances not assumed; more conservative values reported

Table 3. Independent Samples T-Test Comparing Mean Percentage of Words in Written Vs. Video-Recorded Documentation of a Cognitive Type, Across All Project Assessment (n=238)

The mean percent of words from written and video-recorded documentation that fell into "drive" categories is shown in Table 4. The percentage of overall drive words was significantly higher in written documentation for the overall data set only. Risk words (danger, doubt) were significantly higher in written documentation for all four data sets, while achievement words (win, success) were significantly higher in written documentation for the overall data set and one matched data set (paper circuit projects). Power words (superior) were significantly higher in written documentation for one matched data set (soft circuit projects). Affiliation words (friend, social) were significantly higher in video documentation for one matched data set (paper circuit projects), while reward words (prize, benefit) were significantly higher in video documentation for the overall data set and one matched data set (paper circuit).

Drive variables represent the focus of the student. That written documentation expressed more risk-focused conversation could reflect the more analytic nature of that writing with students writing about attempts and failures in design. There is very limited evidence of more power-focused drive in written documentation, but to the limited extent that exists it reflects "people's attention to or awareness of relative status in a social setting" and students might be more willing to reflect on social standing in private writing (O'Dea, Larsen, Batterham, Calear, & Christensen, 2017). The higher achievement focus in the overall and paper craft written documentation makes sense in the context of the gamification platform more focused on points and levels, but the higher reward focus in the same overall and paper craft video documentation could conflict with this assertion as one might also expect a reward focus in gamified writing. This finding could reflect our concerns, however, that students were not overly motivated by rewards like digital badges in the gamification platform, more prone to speak of intangible benefits in the video platform. Not surprisingly for the more social video platform, student talk reflected more drive from affiliation.

	Documentation Source								
	Written (GameLab)			Video (FlipGrid)					
	M	*SD*	n	*M*	*SD*	n	*t*	*p*	ES
Drives	10.87	4.86	164	8.56	3.77	74	3.62	.000	.53
Affiliation	1.88	2.74	164	2.46	2.12	74	*-1.76	.08	-.24
Achievement	5.06	3.10	164	3.42	2.20	74	*4.67	.000	.61
Power	1.51	1.70	164	1.27	1.14	74	*1.26	.21	.17
Reward	1.28	1.42	164	1.68	1.39	74	-1.99	.047	-.28
Risk	1.72	1.31	164	.32	.51	74	*11.88	.000	1.41

*Equal variances not assumed; more conservative values reported

Table 4. Independent Samples T-Test Comparing Percentage of Mean Words in Written Vs. Video-Recorded Documentation Reflective of Drives, Across All Project Assessments (n=238)

The findings suggest written and video-recorded project documentation may contribute unique benefits in at least two ways. In terms of eliciting and supporting analytical reflections, the written platform may offer an advantage. Scores for analytical thinking were higher for all four written data sets, coupled with some indicators of that analytical thinking in a reduced number of data sets, including: more words per sentence (three data sets), more words greater than six letters (two data sets), more usage of descriptive adjectives (three data sets) and quantifiers (two data sets), more usage of categorical articles (four data sets), more usage of risk words (four data sets), and higher overall cognitive processing scores (two data sets). These findings contrast with video documentation that had higher word count (four data sets), greater use different pronouns in varying numbers of data sets, and more usage of affiliation words (two data sets), suggestive of perhaps less analytical and more conversational speak.

In terms of fostering a supportive climate that gives students an opportunity to associate positivity with STEM, video may offer an advantage. Findings revealed more positive emotion words in one video data set, contrasted with more negative emotion words in all four written data sets. Video documentation is a good fit for community-oriented makerspaces and encouraging students to also review and reply to others' videos, particularly in project areas they may not have attempted yet, could generate questions or encourage them to try new projects. There is value in students using social media to post claims and arguments, but also to question and collaborate (Craig-Hare et al., 2017).

One recommendation for leveraging the potential advantages of these two platforms is to combine them in a hybrid system. The challenge, however, is student resistance to documentation and "balancing automated and manual documentation with [the] least disruption of making" (Litts et al, 2016, p. 1046). One approach that would not double the documentation load is to retain reflective writing that may be more analytical as desired, and layer in a social element. For example, students might document their work in writing, but in social spaces like discussion forums, live journals, or blogs, which other students could see and comment on. A makerspace leader might also task student teams with preparing written documentation together in a social portfolio space. Keune and Peppler (2017) analyzed different makerspace portfolio entries and reported that portfolios capturing "shared projects and documentation" were "richer" and showcased better "social engagement" (p. 547). Socially engaged approaches may help to foster interest in STEM, a goal of many informal programs. Pinkard et al. (2017) note that "interest development, particularly for marginalized and stereotyped youth, is not simply an individual accomplishment or discrete activity but a social and interactional process that is often mediated by how students perceive the valued ways of knowing and being of a given practice or discipline" (p. 481). Future research could investigate these two modified approaches to written documentation with a social element to determine how moving written documentation into a public space or encouraging group writing impacts the linguistic results seen.

The findings of this context-dependent, exploratory case study hint at potential advantages to eliciting both written and video-recorded documentation to be confirmed by future research: private, written documentation is more likely to capture evidence of cognitive processing and achievement- or risk-oriented drives, but may be more negative in tone; semi-public, video documentation is more likely to capture evidence of social affiliation-oriented drives and may be more positive in tone. Future research should investigate linguistic impacts given merged approaches of reflective writing for social spaces, or reflective writing in social groups.

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