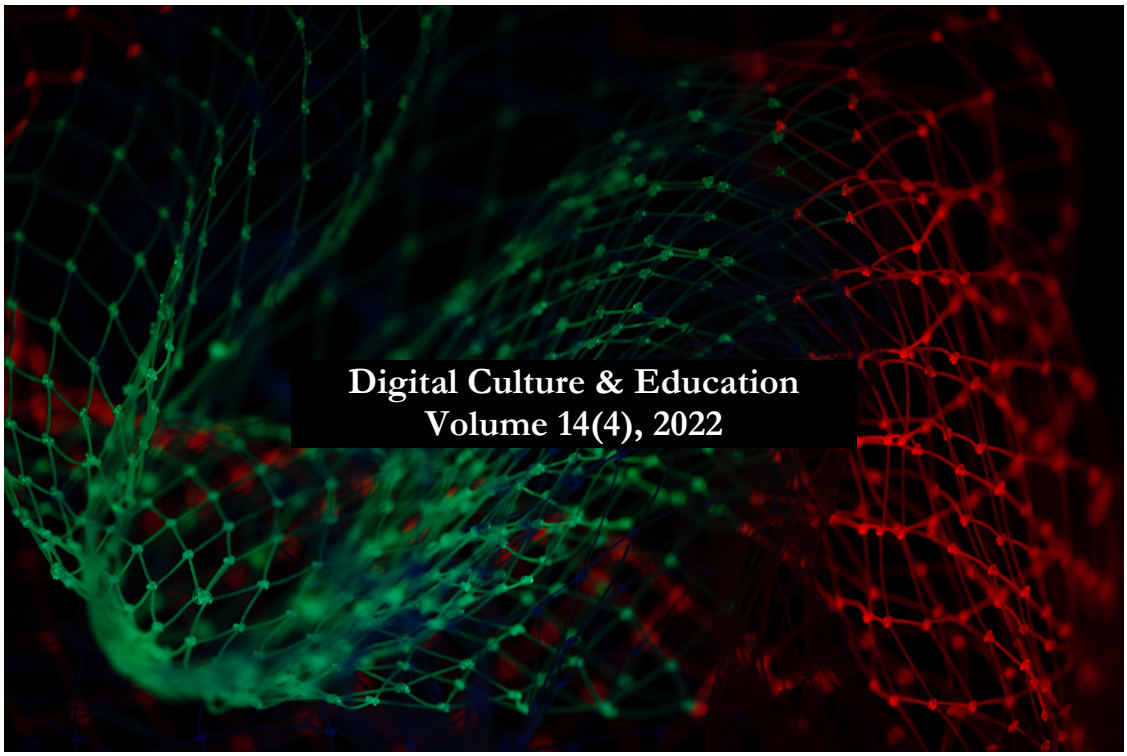

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ALGORITHMIC LITERACIES: IDENTIFYING EDUCATIONAL MODELS AND HEURISTICS FOR ENGAGING THE CHALLENGE OF ALGORITHMIC CULTURE

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Abstract: *Algorithms are interwoven in the fabric of digital culture. They increasingly mediate our experience of politics, culture, identity, and agency. Building on critical research in other fields, critical educational theorists are exploring the pervasive role of algorithms, AI, and 'smart learning' tools in reshaping what and how we learn. This work is articulating new critical literacies adequate to the challenges of 'algorithmic culture', where algorithms co-produce, with users, differentiated media experiences, knowledge, affinities, and communities, as well as new patterns of identity and embodied action. This article examines how educational theory is responding to the dramatic shifts in digital experience precipitated by algorithmic systems and explores how educators can support students in developing critical literacies and technical skills for navigating emerging algorithmically-mediated worlds. We offer conceptual and pedagogical heuristics to educational researchers and educators for navigating the challenges of algorithmic culture, as well as identify risks associated with the migration of big data techniques into formal educational spaces.*

Keywords: *algorithms, algorithmic literacy, data literacies, education, game design, social media*

Introduction

Algorithms mediate our online actions, experience, and forms of community. Algorithms increasingly modulate our experience and understanding of place, politics, culture, identity, and agency (Beer, 2017; Bucher, 2018; Willson, 2017). An algorithm is a set of rules–or computational procedures–for solving a problem or executing a task. In online spaces, algorithms are computational procedures for 'doing things' with user input (data) and for automating various pattern-seeking or decisional outputs: for example, sorting, filtering, analyzing, ranking, recommending, and distributing digital content or interactive experiences. Google PageRank and Facebook algorithms are perhaps the most well-known algorithmic tools.

Algorithms influence what people experience online, the communities they affiliate with, how they interact with others, and how they may come to understand themselves. If algorithms can be said to have social and rhetorical power (Bucher, 2018), that power resides in how they surveil users, collect and aggregate user data, and classify users. As well, they determine what is 'relevant' or visible to users. By implication, algorithms determine what is excluded from digitally mediated experience. Far from being neutral tools, algorithmic systems are culturally situated, human-made artefacts which reflect the goals, biases, prejudices, and values of their programmers (Kitchin, 2017; Williamson, 2018). The proliferation of algorithmic systems in social media environments, and the exponential increase in available user data to feed their operations, have led some scholars to refer to an 'algorithmic turn' in media culture (Lim, 2020).

Building upon work in media studies, educational theorists are beginning to explore the pervasive role of algorithms in reshaping what and how we learn and know, including language and literacy practices, knowledge making, and new forms of identity construction. Related research calls for supporting students in developing data literacy (Markham, 2020), critical algorithmic literacies (Sengupta & Hill, 2021), and 'pragmatic competences' for navigating algorithmically mediated environments (Jones, 2020). Cope and Kalentzis (2016) and Williams (2018) alert us to where and how 'data science epistemologies' are migrating from corporate contexts to formal educational spaces, asking critical questions about the impacts of these rapid transformations.

We argue that traditional forms of critical media literacy are no longer adequate for emerging forms of algorithmic mediation in digital culture. Existing critical media literacies have focused on systems of digital representation, multimodal discourse analysis, narrativity, visual culture, and ideology (Buckingham, 2007; Luke, 2012; New London Group, 1996). These literacies interrogate how particular perspectives, interests, and power-relations are rhetorically embedded in representational systems. They support in identifying where and how dominant social narratives, constitutive discourses, and normative identities are communicated through new media, particularly where (mis)(under)representations of race, gender, sexuality, culture, and class are in play. Informed by democratic aims, this educational work enables students to understand and transform the sociotechnical systems they encounter. Congruently, Kellner & Share (2007) assert that educators should empower their students to produce their own alternative and 'counter-hegemonic' media.

Emerging algorithmic systems, however, complicate our media landscapes as they influence architectures of experience and 'choice' in ways that prefigure and mediate what is represented to individuals. Algorithms, the datafication of user experiences, and big data techniques are intangible: their power lies in how they collect data about people and administrate digital environments behind the scenes (or behind our screens). Algorithmic systems are best approached as invisible intermediaries (Burbules and Callister, 1996) that co-produce, with individual users, differentiated media experiences, affinities, and patterns of meaning-making, without the user's agreement or awareness. As such, algorithmic systems shape and solicit–across devices and

networked environments–haptic patterns of embodied interaction and affective response, as well as routine 'performances of self' (Hogan, 2010).

This article presents theoretical and pedagogical heurists that support researchers and educators' responses to dramatic shifts in digital and online experience precipitated by the challenge of 'algorithmic culture' (Striphas, 2015), considering questions regarding the stakes of datafication and big data techniques; theoretical frameworks and pedagogical practices leveraged to understand and support students' critical engagement in networked environments where algorithmic mediation is in play; and what stakes are in play in relation to language, literacy, and knowledge making, as well as identity formation and learner agency. In addressing these questions, we map out critical orientations in educational research for: 1) supporting students in developing a conceptual understanding of algorithmic systems, their impact on shaping information and cultural content, as well as meaning-making and identity, and of literacies for navigating and challenging algorithmically-mediated environments. 2) we advanced hands-on computational practices as means to cultivate critical technical knowledge of the mechanics, conditional logic, and parametric relations associated with algorithmic procedures.

The challenge of algorithmic culture

Computer algorithms are employed in many contexts. Speech-recognition algorithms support augmented and alternative communications devices for diverse users and persons with disabilities. Learning simulations use algorithms to help us learn about and model the impacts of climate change. Algorithms can also be trained to evaluate patterns in human data in ways that circumvent forms of unconscious human bias. In online and networked environments, however, algorithms have been increasingly implicated in new surveillance cultures (Zuboff, 2017), in social sorting and hegemonic power/knowledge relations (Beer, 2017; Bucher, 2018), and in exacerbating racism, discrimination, and inequality (Noble, 2018; O'Neil, 2016).

Laying groundwork for contemporary discussions, media scholar Mark Poster (1995) anticipated that the convergence of surveillance technologies, the digital database, and what we now call datafication would become a "new arena of contestation" (p. 93). Before the use of algorithms in online environments, scholars in surveillance studies, STS, and related fields charted the vocabularies and controversies found in contemporary algorithmic culture: questions about how digital technologies co-configure users' actions and future behaviors (Woolgar, 1991); concerns about privacy, power, and identity construction in online environments; and explorations of how 'smart machines', in affording particular actions, also modulate our intentions and constrain human agency (see Latour, 1996; Law, 1990; Zuboff, 1988).

In the 1990s, educational theorists were tempering utopian visions of digital media, reminding us that, even as internet hypertext media might disrupt social hierarchies and the power structures of 'print culture,' digital media were still rule-bound systems governed by protocols and "intermediaries, both visible and invisible" (Burbules & Callister, 1996, p. 44). If early work on cyberculture often celebrated the democratic or implicitly emancipatory promise of the web–where environments were as theorized as convivial, rhizomatic, and inclined toward unpredictability–Moulthrop (1994) cautioned that these systems were, after all, "entirely routinized contrivances…composed of discrete rules and relationships, designed to be regular and reliable even in their 'vastness' and 'randomness'" (p. 310). Burbules and Callister (1996) similarly signalled that emerging media might be structured in ways that "are potentially much less democratic and more restrictive and hegemonic than is now possible with simpler information systems" (p. 45).

To the point, Roger Clarke advanced the terms 'digital personae' (1993) and 'dataveillance' (1988)

to describe how database models of individuals were being constituted through the surreptitious collection and statistical analysis of data about them. Clarke (1993) warned that "the physical persona is progressively being replaced by the digital persona as the basis for social control by governments, and for consumer marketing by corporations… [which will] inevitably result in impacts on individuals which are inequitable and oppressive" (p. 91). Poster (1995) predicted that this kind datafication–or translation of life activity into data–would lead to new power/knowledge relations (Foucault, 1995). Beyond oppressive corporate or state uses/abuses of this aggregated data (knowledge) of and about individuals, Poster also predicted that resultant digital personae–or 'databased selves'–would come to address individuals themselves in online environments, inscribing "new patterns of interpellation" (p. 90). For Poster, datafication would lead to new 'modes of address' where our 'databased selves' might impose reductive schema on us, and communicate normalizing representations about who we are, what we do or imagine.

In 1994, Philip Agre described new forms of computer-age surveillance that anticipated how algorithms work today in shaping our attention, behaviors, and choices. For Agre, we were experiencing a shift in surveillance culture from older forms of control–based on optical metaphors like observing or being 'watched'–to an emergent *capture* model of surveillance. The capture model of surveillance implied both the datafication of human action/behavior, as well as an implicit procedural structuring and real-time coordination of user actions (e.g., for efficiency, optimizing performance, or compelling/proscribing certain behaviors). The risk was not simply in how algorithmic systems collect data and track user actions, but in how they might come to script human behaviors and predetermine user "grammars of action" leading to a "transparency of correspondence between digital representations and…embodied activity" (Agre, 1994, p. 107).

These speculations became realities. Interfaces that connect surveillance tools, databases, and human users have led to ever more reciprocal and mutually-modifying relations between machines and humans. Algorithms play a significant role in mediating user experience across mobile devices, tablets, smartphones, VR headsets, wearables, and even household appliances. Algorithms blur traditional boundaries between public/private, work/leisure, formal institutions and everyday life. Corporate and state institutions develop ever more dynamic means of aggregating user data, surveilling movements and behaviors within and across software platforms and geolocations, and analyze data gleaned from users' input, actions, and reactions. Contributing to public acceptance of algorithmic culture, corporations habituate users to acknowledge they are being tracked, invite users into various customization processes to extract data and personalize experience, and use clickwrap to facilitate the circumvention of privacy and consent materials (Obar & Oeldorf-Hirsch, 2018).

Algorithmic data collection plays a key role in tracking everything we do, from making purchases and online data searches, to time spent on websites and using health/fitness wearables that collect biometric data. Social media platforms invite users to provide personal data through user profiles, photo uploads, 'liking', 'friending', 'following', and 'hash-tagging' content. Communication with natural language processing (NLP) derived digital assistants, such as Siri and Alexa, utilize affective computing techniques to give non-human agents a 'human' hue–and further extend algorithmic mediation into everyday life.

Algorithms are increasingly a part of everyday discussions and 'cultural imaginaries' (Bucher, 2017). Terms like 'algorithmic bias,' 'filter bubble,' and 'echo chamber' have become common in public discourses surrounding social media (Kitchens, Johnson & Gray, 2020), indicating that technology users have come to infer, and even accept as normal, that engaging with algorithmic systems means that algorithmic systems surveil and compile data about us, engage with us, compel our actions, and delimit horizons of possible experience, affiliation, and communicative action.

Algorithmic 'world making'

Recent innovations in machine learning (ML) and AI have not merely amplified earlier concerns about dataveillance, digital personae, and social sorting, they have transformed interactive environments into ever more refined systems for classifying, predicting, filtering, and distributing content and experience to unique users. Advances in ML, where sets of algorithms are trained to work together to perform more complex decision-making operations, often function in unintended ways that transcend the original goals and constraints set by human programmers, in turn amplifying biases or implicit prejudices (Hall *et al.,* 2022). Insofar as algorithms and machine learning tools are entangled in evolving modes of social power (Beer, 2017), they co-construct, with discrete users, horizons of what is seeable, sayable and sensible (Bucher, 2018), as well as affective orders of affiliation (Lim, 2020) that may resolve, and feed-back into, enclaves of identity and repetition of the same. Crawford (2021) asserts that the way data "is understood, captured, classified, and named is fundamentally an act of world-making" (p. 166).

In any educational discussion of algorithmic culture, we must examine how algorithmic mediation is implicated in world-making, and in rhetorically and procedurally shaping, for particular individuals, specific social relations, interests, affinities, tastes, political communities, subject positions and speech acts. Today, students experience, learn, play, make sense, communicate and come to understand themselves and others within increasingly regulated online worlds governed by these algorithmic intermediaries.

While there is debate on the extent to which algorithmic world-making threatens democratic institutions, Stark and Stegmann (2020) suggest that the risk of 'ideological homophily', political polarization, and societal fragmentation persists, particularly where there is rapid dissemination and (re)circulation of disinformation within social networks. Michael Peters (2017) asserts that post-truth epistemologies are bound up with algorithms, where machine "selected news sources reinforce existing prejudice" and create ideological "bubble worlds" (p. 564) in which fake news, disinformation, and conspiracies flourish.

Regardless of whatever insular or differentiated worlds are co-constructed for discrete users, *all* media users are collectively encouraged to behave routinely and regularly in online environments. Given that attention itself has become a commodity (Wu, 2017), algorithmically directed modes of address– 'hails', 'nudges,' 'alerts,' 'pushes' and reward mechanisms–operate across platforms and devices with the aim of establishing affective and attentional commitment on the part of users. Under these conditions, Citton (2017) asserts that "there is no vestige of what used to be everyday life beyond the reach of corporate intrusion" (p. 264), and the 24/7 "compulsory functionality" (p. 344) of networked media. Users are algorithmically 'hyper-nudged' (Yeung, 2017) with recommendations and reminders to 'engage'. Email, vibrating haptics, and ringtones relentlessly alert us to the activities of 'friends,' workout goals, breaking 'news', lifestyle 'hacks', and micro-personalized advertising. Similarly, social media users are encouraged to boost their own symbolic capital through participating in and extending their social networks. For younger users, tools like Snapchat routinize photo-sharing gestures, and even generate interactive maps that enable users to track the location and movement of 'friends' in real-time, contributing to novel disciplinary modes of user *coveillance (Mann, Nolan & Wellman, 2003).*

Zuboff (2017) asserts that algorithms, as tools of surveillance capitalism, instrumentalize "human behaviour for the purposes of [behavior] modification prediction, monetization, and control" (p. 352). This is alarming given how attention and interaction is coordinated across spaces, times, devices, and physical/mobile environments, where 'grammars of actions' (Agre, 1994)–look, like, tap, swipe, reply, follow, post, emote–become entrained into our repertoire of autonomic gestures and everyday embodied habits. Social media users are inured to rely on external authorities or other

people for recognition or validation Accordingly, algorithms play a role in coordinating interaction across social media platforms: they pre-script discourse procedures (e.g., in 'tweets') where routinized micro-performances, generic soundbites/memes, and causal re-tweeting/hearting stand in for, and flatten, opportunities for rigorous discussion or meaningful forms of artistic or cultural exchange.

While social media offer countless sites for communities of practice, informal learning and technique sharing, and DIY and youth-directed participatory making, these same 'participatory cultures' (Jenkins *et al.,* 2006) are, today, being recoded from the inside out by algorithmic culture (Lotherington *et al.,* 2021). Participation and interactivity (emancipatory features of Web 2.0) are inexorably reduced to new modes of formularized interpassivity, and 'creative making' is driven less by curiosity, inquiry, or intrinsic purposes than by the aspirations of 'creators' to extract others' attention and be validated through 'likes', or some other means of extrinsically motivated exchange value. User-generated content, the animating force of social media platforms like YouTube, TikTok, Instagram, Twitter, and Facebook, unavoidably coordinate new forms of disciplinary coveillance*,* where users are invited to surveil, judge, and actively police others' bodies, actions, and creations *(Mann, Nolan & Wellman, 2003).*

Educational interventions: Responding to the challenges of algorithmic culture

Recent calls to develop *critical* algorithmic literacies have been articulated in many ways. We examine, in what follows, how educational theory is responding by: supporting students in becoming *aware of the pervasive use algorithms across networked environments; understanding what algorithms do and how they work; and supporting learner agency in questioning algorithmic authority.* At this level, 'data literacy' and 'algorithmic literacy' can be defined in terms of critical/conceptual understanding, developing skills for navigating algorithmically mediated environments, and developing pragmatics for contesting oppressive or normalizing modes of algorithmic address. Second, we examine how educational theory is supporting students in gaining technical skills and applied knowledge of the mechanics, conditional logic, and parametric relations associated with algorithms and algorithmic world building. At this level, algorithmic literacy is connected to practice-based critical pedagogies where algorithmic thinking, critical making/coding, and digital design (e.g., game making) are in play.

Conceptual knowledge, building algorithmic awareness, and critical literacies

Algorithms play a significant role in circulating misinformation and fake news. They contribute to channeling microtargeted ads and political content to users in ways that threaten democratic institutions (Peters, 2017). At the most fundamental level of news consumption and (dis)(mis)informational content, much work has been done to foreground the constructed nature of algorithmically mediated experiences and to support students in understanding how emotion and information 'flows' are algorithmically shaped/interwoven in 'post-truth' contexts (see Goering & Thomas, 2018; Janks, 2018). Algorithmic literacy includes practices that invite students to examine the implicit rhetorical functions of search-tools (e.g., Google's PageRank algorithm) in terms of ranking, privileging, excluding, or customizing results, and how variables like user 'identity' or location impact different outputs (Bakke, 2020). Obar (2021) further advances source triangulation techniques where students actively seek out and contrast diverse and competing information sources and ideologically conflicting narratives. Practices like source triangulation enable students to splinter ideological 'bubble worlds' by bringing multiple and dissonant narratives into view. Students examine issues like source diversity, genre, credibility, emotional entanglement, and evidence, and reflect on the roles algorithms play, rhetorically, in mediating

(mis)representations. Fittingly, they are invited to reflect on their own positionality within these landscapes of directed meanings (Smith & Parker, 2021).

Drawing upon a multiliteracies framework, Leander and Burris (2020) identify question-posing pedagogies for exploring how algorithms are implicated in modes of knowledge construction and student identity formation. Speaking to concerns about AI and the construction of 'surrogate identities' (digital personae), educators are invited to co-explore, with students, techniques for identifying gaps "between how an algorithm identifies us and how we want to think about ourselves" (p. 3). Educators are urged to advance epistemological and ethical questions about who owns, designs, and benefits from big data techniques, and how bias, discrimination, and racism may be remediated in the algorithms of search engines, image-generating AI, and social media feeds.

This research is emblematic of how multiliteracies pedagogies can be retooled to examine the ways algorithms serve to advance, explicitly or incidentally, dominant ideologies, and how students can position themselves critically as they encounter representations, make meanings, and create new knowledge. Discussions about deep fakes, the use of biometric data, algorithmic bias in machine learning training sets, and the encoded genre conventions in AI-generated art/images/cultural texts (see Manovich, 2019) are rich points of departure for critical inquiry and dialogue. In terms of world building, other researchers leverage multiliteracies frameworks for considering place-based inquiries that enable students to explore how tools like Google Maps encode – representationally and algorithmically – dominant historical narratives into commonly used visualization media (Thumlert *et al.,* 2020).

Other work on 'data literacy' (Lomborg & Kapsch, 2020) examines how different internet users come to welcome, negotiate, or actively challenge algorithmic mediation in their lives, and how people come to sense gaps or tension in their relationships with algorithms. Given the 'black-boxed' nature of these systems, data literacy is promoted through "showcase[ing] real life examples of algorithmic work in different contexts, relatable to the life of ordinary people," as a means of supporting personal agency and collective responsibility (p. 759). Markham (2020) defines data literacy as "a type of awareness and curiosity that leads to developing competencies needed to grapple with the complex impacts of digital transformation on individual and cultural wellbeing" (p. 229). Using critical pedagogy frameworks, Markham dramatizes the opportunities of multimedia installations, interactive artworks, and storytelling to provoke a multiplicity of critical questions about data mining, surveillance, movement tracking, and algorithmic decision-making, as well as the storage/use of our own memories. For Markham, the goal of this work is to "spark" deeper reflection (p. 227) and "a stronger critical consciousness" (p. 229). Through interactive engagement and experimentation with exhibit media, participants come see there is "a crisis that needs to be addressed" (p. 235). In turn, data literacy leads to better questions, further curiosity, and "critical reflection about the situatedness of one's own role, position, and ethical stance in the situation" (p. 235).

Extending opportunities for student self-reflexivity, Pronzato (2021) builds upon a critical pedagogy framework to advance auto-ethnographic diaries as a means of activating student reflection on even the most banal dimensions of online interaction. Koenig (2020) further shows that when students keep media journals, consciously verbalize, and write about their mediated learning experiences, they move from seeing algorithms in terms of basic 'outputs' or 'results' and become "more critically and rhetorically aware of just how influential algorithmic systems are in their lives" (p. 12).

Formal systems: Pragmatic competences, 'tactics' and sousveillance

For Nolan, Raynes-Goldie and McBride (2011), the question of algorithmic mediation in education centres on formal questions of how the filtering and choice-architectures endemic to new media may come to establish dependency upon interactive tools, leading to a 'heteronomous' conditioning of children. Regardless of ideological contents, under conditions where filtering agents and choice-structuring software are in play, learners become "used to dependence on [human or non-human] others to make decisions for them" (p. 26). The authors argue that opportunities for open-ended, self-directed inquiry are thus restricted, and occasions for becoming more autonomous learners are foreclosed.

Drawing upon speech acts theory, Jones (2020) argues that the first step in supporting a formal, critical 'pragmatics' is to regard digital media not simply as information systems, but as perlocutionary action systems designed to "compel us to act in particular ways" (p. 10). Jones (2020) dramatizes how, over the past decade, the 'semantic web' (Berners-Lee, 2001)–composed of machine-interpretable texts–has become more and more entangled in an evolving 'pragmatic web' composed of machine-interpretable *actions*, where students and computer systems make meaning and knowledge, together, in real time.

Against semantic backgrounds, algorithms act and do things with students: they predict what is most 'relevant', curate content, sequence what comes next, anticipate our inquiries, correct our errors, complete our sentences/thoughts for us, and so on. Rather than uncritically accept orders of dependence, or allow algorithms to 'think' for us, Jones suggests that students need to develop practices for understanding how algorithms rhetorically co-ordinate context-specific learning events and meaning-making acts. Jones' work (2020) provides a granular means of examining how algorithms play a role in both constraining and compelling learning actors in particular learning situations. Insofar as algorithms make inferences about users, pragmatic competences support student reflection on the "inferential processes they themselves develop as they interact with both human and non-human actors within the pragmatic web" (p. 15). This means supporting situations for students to situationally grasp how algorithms privilege (or exclude) certain texts, experiences, and representations, as well as modulate present and future possibilities of action, thinking, writing, and inquiry.

Jones' work enables us to better understand how other theorists are developing practices for subverting or 'gaming' the logic of algorithms across social media platforms. Willson & Kinder-Kurlanda (2021) and Swart (2020) theorize modes of algorithmic literacy using de Certeau's (1984) notion of *tactics:* the ad hoc practices of everyday actors enacted against the dominative strategies of more powerful systems–in this case, datafication. Tactics, in this context, requires users to in some way interpret the goals, tacit rules, and design of algorithms with the aim of benefiting from, circumventing, or "resisting the impulsions written into the codes" (Beer, 2009, p. 998). Willson & Kinder-Kurlanda (2021) detail how social gamers address their own visibility and privacy concerns by developing 'obfuscation' techniques to remain anonymous or protect personal data. Swarth (2020) further argues that we need to empower students with algorithmic 'tactics' so they can navigate increasingly personalized media landscape and push back against systems that seek to define reality for us.

Mann, *Nolan* & Wellman (2003) invented a more playful, situationist and community-driven variation on de Certeau's 'tactics' which they called *sousveillance*. They define sousveillance as tactically observing and documenting surveillance systems 'from below'. Sousveillance is a mode of self-empowerment that pivots on actively inverting the gaze of contemporary surveillance technologies (p. 336). As a critical practice, everyday actors resituate technologies of control by 'watching the watchers', and collecting and sharing data on surveillance tools/techniques. The

sousveillance model was designed to address panoptical (Foucault, 1995) modes of modern surveillance and self-regulation, and to creatively disrupt public acquiescence to surveillance cultures. Retooling sousveillance for algorithmic culture, educators might enable learners to play with and against algorithmic rulesets and constraints, and to creatively document when, where, and how algorithms are coordinating homophilic experience, exacerbating inequalities, or addressing persons into specific narrative positions, affective postures, consumerist identities, and/or 'nudging' certain behaviors or emotional reactions. As a model, sousveillance provides opportunities for communities of learners to tactically produce 'counter-hegemonic media' (see Kellner & Share, 2007) in ways that document or tell stories about where and how algorithms work in their lives, or are interwoven in everyday world building. Students can accordingly be empowered to move beyond intuitive 'folk theories' about algorithms and begin to approach them as objects of critical inquiry and creative repurposing.

Technical knowledge: Critical computational literacies and game design

The critical approaches outlined above provide conceptual and pragmatic heuristics. Other theorists argue that individuals in contemporary democracies also need to have practical knowledge–that is, technical know-how–of the underlying algorithmic protocols and coding operations in play (Galloway, 2004). To this end, researchers in education are developing pedagogies that infuse computational thinking with the reflexive work of critique (Dasgupta & Hill, 2021; Kafai, Proctor & Lui, 2020). As a whole, this work shows how critical computational literacy can provide transparency into algorithmic systems, while also providing students with the coding skills to resist them, and/or mobilize coding for more creative and transformative social purposes (Lee & Soep, 2018; Proctor & Blikstein, 2019).

Kafai, Proctor & Lui (2020) argue that students need to be able to analyze the "inequities caused or exacerbated by the societal impact of computing" (p.102) as well as related issues like data harvesting, surveillance, and election manipulation (cf. the Facebook/Cambridge Analytica scandal). These authors argue for the alignment of computational literacies with social justice education. Similarly, Dasgupta and Hills (2021) model "authentic community-centered approaches for navigating ethical dilemmas as designers" (np). Developed for the *Scratch* community, their orientation to algorithmic literacy promotes coding practices that lead to programmer reflection on data collection and privacy concerns while establishing 'sandboxes' for examining potentially 'dangerous ideas.' Other research explicitly connects coding literacies with the critical multiliteracies agenda of the New London Group (NLG) (1996). Mertala (2020) employs NLG's 'critical framing' techniques, mapping point-by-point relations between the 'functional' dimensions and the 'critical' dimensions of programming: technical outcomes and algorithmic solutions are juxtaposed against the social impacts of programmer choices, including issues related to surveillance, privacy, tracking, 'data doubles', bias mitigation, and increased public governance of technical innovations.

While the research above speaks largely to computer science education, game design pedagogies help leaners understanding algorithmic culture through interdisciplinary pedagogies of making (Thumlert, de Castell & Jenson, 2018). Here, Galloway (2004) reminds us that digital games are, at their core, algorithmic: players must in some way interpret or intuit algorithms to negotiate game worlds, challenges, and software boundaries. Murray (1997) demonstrates that, as games and simulations model worlds or represent stories, they also execute arguments, algorithmically, with players at the level of interactive, process-native experience. Salient to algorithmic culture, these discussions highlight the ways computational environments inter-operate with users in real time, where meanings are communicated as much by the protocols/procedures of software as through aesthetic, narrative, or representational techniques (Bogost, 2007). Gee (2003) similarly shows how

digital game play affords an embodied empathy for complex (algorithmic) systems by situating players as active, role-taking participants *within* dynamic procedural models.

Alongside game play, Thumlert *et al.* (2020) suggest that digital game making provides a yet more nuanced context for a hands-on understanding of algorithmic processes, where students are actively involved in building models, micro-worlds, and story/simulation systems. Even in simple games, algorithmic processes, if/then conditional logic, and parametric relationships–are interwoven and in play at the level of a game's design. Further, critical game design models provide opportunities for creating alternative and even subversive uses of game software (Flanagan, 2009). For example, Flanagan and Nissenbaum (2014) analyzed the implicit values, ideological constructs, and normative representations embedded in mainstream video games and developed a critical design process that promotes alternative narratives, identities, and values. This model enables students to consider and encode very different axiological variables like diversity, inclusivity, cooperation, and conviviality into the core mechanics, rule sets (algorithms), player-relations, and win-conditions of games.

Providing hands-on engagement with algorithmic operations, open-source tools like *Twine* provide 'low-threshold high-ceiling' environments to explore interactive game choice-architectures, HTML, JavaScript, and if/then conditional logic. Game design tools like *Unity* provide environments supportive of more complex algorithmic literacies. *Twine* has a long history of introducing students to coding while providing opportunities for exploring the creative and critical possibilities of algorithmic culture (Salter & Moulthrop, 2021). As students design games, they learn to deconstruct, prototype, mod, tinker, and hack algorithmic systems and rule sets. Thumlert *et al.* (2018) assert that game making for learning supports students in moving beyond consumer-level technological proficiency to enact "producer-like dispositions": as they "open the black box of algorithmic culture", students "explore how procedural logic and conditional operations function" (p 710). This enables students to productively explore how "algorithmic systems and mechanics can work towards students own critical and creative purposes" (p. 710).

Recent pedagogical research (Thumlert, de Castell & Jenson, in press) shows how students develop alternative games that reflect upon their situations within social and technical systems: for example, interactive games about how gender bias in schools or workplaces implicitly (i.e., algorithmically) push girls/women away from STEM interests; games about racial bias and profiling in workplaces; and games about identity, cyberbullying, and the impacts of (social) media systems on wellbeing. As Markham (2020) points out, interactive art installations 'spark curiosity' about algorithmic systems. Through designing their own in interactive game systems, students can spark their own curiosity and inquiries and, accordingly, engage algorithmic literacy as skilled practice. Further, by becoming, to varying extents, technically competent with algorithmic procedures and design practices, students gain practical insight into how algorithmic systems operate–and interoperate–with people in everyday life.

Algorithmic culture in educational institutions

As we outline educational heuristics and critical pedagogical models for responding to the challenge of algorithmic culture, algorithmic techniques are, at the same time, rapidly drifting into formal educational institutions. As Peters (2017) signals, education institutions have, to a large extent, been captured by big data systems across administrative, research and teaching domains. Stockman & Nottingham (2022) assert that datafication and surveillance capitalism are already the accepted models for 'Edtech' in schools. Cope & Kalentzis (2016) and Williams (2018) alert us to how corporate 'data science epistemologies' are being welcomed as part of a new hegemonic common sense in schools. Under these conditions, there is a very real risk of a rescripting

educational priorities, epistemologies and practices in ways that outpace our ability to challenge such transformations.

Corporate algorithmic culture arrives in educational spaces through many vectors. They arrive through datafication tools introduced by institutions to predict and organize student educational pathways; through smart learning tools and tutoring systems that 'optimize' personalized learning environments; through varieties of software tools that interact with and assess learning, and aggregate student assessment data for sorting and accountability purposes; and through the integration of social media and corporate designed learning tools, e.g., Mobile Assisted Language Learning (MALL) apps.

As noted previously, algorithms mediate power-relations as part of a broader network of human and non-human actors: datafication tools and machine-learning techniques exert the power to name, rank, and place. They "feed into people's lives, shaping what they know, who they know, what they discover, and what they experience" (Beer, 2017, p. 6). To understand how algorithmic mediation might feature in educational systems, we do not need to look beyond education itself for a conceptual figure, as modern educational institutions have always operated algorithmically. That is, the techniques associated with algorithmic classification and decision-making have long been embedded in the procedural mechanics of educational systems, including institutionalized 'algorithms' that reproduce social inequalities (see Bourdieu & Passeron, 1990). Schools and algorithms do similar things: they identify, sort, and place individuals; they establish architectures of 'choice' and guide individuals through differentiated curricular pathways. Implicitly or explicitly, they anticipate destinations through procedures like naming, tracking, ability grouping, ranking, assigning 'giftedness' status, or remediating giftedness' opposites. While 'algorithms of oppression' may be embedded in tools like Google and Facebook (Noble, 2018), they are also longstanding features of educational systems (Giroux, 1983).

We are not asserting that institutions can be simply equated with algorithmic operations or reduced to cybernetic metaphors. We are asserting, however, that in the effort to translate machine learning and big data techniques into educational contexts, there is a real risk of perpetuating–or exacerbating–those very institutional techniques that have been shown to be deeply problematic in relation to social sorting, social reproduction, and exclusion.

Given that educational institutions aggregate enormous volumes of student data, claims about AI in education tend to focus on innovations that leverage this data to personalize learning. AI and machine learning tools are seen to provide learning 'solutions' that adapt curricula to individual students' needs or levels of knowledge. It is asserted they can locate 'gaps' in knowledge and analyze students' previous experience to identify weaknesses and 'improve' personalized experience with customized, interactive feedback (Munir, Vogel & Jacobsson, 2022).

Behind the veneer of technocapitalist innovation, however, critical researchers argue that these same tools narrowly define what counts as learning, narrowly delimit how people learn, and abstract learning from cultural contexts. While smart tools may 'personalize', they are nevertheless built upon input-output, assembly-line logics utilizing anachronistic learning theories based in cognitivist/behaviorist traditions. For example, Williamson (2018) states that big data epistemologies necessary "reflect the idiosyncratic thinking of data science", whose educational theories view learning as "quantifiable, measurable, actionable, and therefore optimizable" (p. 119). Yet, as AI researchers assert, data science techniques abstract and flatten particularities of human identity, culture, history, language use, and possibility. When applied to social and institutional contexts for the purposes of sorting, personalization, predicting, and optimizing environments, algorithms have the capacity to reproduce and amplify existing structural inequalities (Crawford, 2021), inscribe standards of normalcy, abnormality, or deviance (Beer,

2017), perpetuate racialized and gendered hierarchies (Hall & Clapton, 2021), and cement ableist ontologies (Shew, 2021).

Williamson (2018) further states that smart learning tools organize "students' probable future progress through predictive analytics processes and… 'personalize' access to knowledge through modularized connections that has been deemed appropriate" by the system (p. 155). Selwyn (2019) suggests that under conditions where tools sequence and regulate personalized experience for unique students toward fixed outcomes, "any intelligent tutoring system or pedagogical agent is essentially a form of individually focused behaviour management" (p. 69).

Smart tools, as well as corporate language learning and assistive writing apps, may also reinforce standardized/universal forms of language and literacy that privilege students from dominant linguistic and cultural backgrounds. For example, corporate language learning apps are a form of MALL that displace educational theories/practices that see meaningful learning grounded in social action, and in diverse linguistic contexts and uses (Lotherington *et al.,* 2021; Shorrt, 2021). Symptomatically, within smart learning worlds, learning itself may be dissociated from social use, student purposes, and the particularities and textures of everyday life. At the same time, in order to 'stand in' for intrinsically motivated forms of student inquiry, the algorithms of learning apps often incorporate gamification techniques and extrinsic reward systems to 'motivate' students through rote learning, quizzes, drills, and decontextualized skills learning (Nolan & McBride, 2014). Commonly used AI-driven corrective writing and assessment systems roll back decades of research in New Literacies studies and sociocultural learning theory. If utilized uncritically, they abstract language and literacy from social practices, and prescribe generic, one-size-fits-all formulae for writing and literacy learning that can disenfranchise vulnerable populations (Selwyn, 2019; Toncic, 2020).

As AI researchers have long pointed out, machine intelligence is poorly suited to support or respond to the situated actions of learners where inquiry, emergent interests, and ad hoc responses to material challenges or the actions of others are in play (Bowker & Starr, 2000; Suchman, 1987). Smart learning tools substitute screen-based *representations* of actions and processes for the *actual* actions, tangible processes, and use of tools where learning happens in authentic environments and domains of practice. While smart tools may efficiently sequence and compel actions, they cannot accommodate or respond to the idiosyncratic contingences of situated action where meaningful learning occurs, or where unforeseen relationships or intrinsically motivated learning trajectories eventuate.

With regard to technology use in education, problems do not necessarily always lie with the tools. As Thumlert *et al.* (2015) and Short *et al.* (2021) point out, actors in educational institutions typically integrate learning technologies to accord with their standard 'by-the-book' curricular uses, without considering how these tools might be reimagined or resituated. Accordingly, educational researchers might consider exploring research questions that are focused less on the 'efficacy' of corporate learning apps and investigate how educators are creatively re-purposing or re-contextualizing these apps in relation to more purposeful, situated, and meaningful forms of learning, doing, and making.

Conclusion

We outlined educational heuristics and pedagogical models for responding to the challenge of algorithmic culture. For future educational research, we would like to signal opportunities for exploring how critical *conceptual* literacies about the role algorithms play in everyday life can be interwoven with *technical* practices like critical coding, student media production, and digital game

design pedagogies. This research can advance an understanding of algorithmic literacy *as* skilled practice.

Critical research tends to dramatize the oppressive aspects of algorithmic culture. We encourage future research to investigate where and how algorithmic programming might actually serve social justice and EDI purposes, for example, through using AI ontologies and training sets designed to not merely 'mitigate' bias, but to shift toward circumventing and actively thwarting forms of bias, as well as ableist, gendered, and racist assumptions and classifications that reproduce inequalities in schools. In regard to social media and corporate learning apps, we suggest that teachers and students today might best be served through educational research that explores how experts and skilled practitioners outside of schools are critically mobilizing, or repurposing, different applications–and in ways that advance their own learning purposes, expertise, and competencies in authentic domains of practice.

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References

Agre, P. (1994) 'Surveillance and capture: Two models of privacy', *Information Society,* 10(2), 101–127.

Bakke, A. (2020) 'Everyday Googling: Results of an observational study and applications for teaching algorithmic literacy', *Computers and Composition*, 57, 1-15.

Burbules N. & Callister, C. (1996) 'Knowledge at the crossroads: some alternative futures of hypertext learning environments', *Educational Theory,* 46(1), 23-50.

Beer, D. (2017) 'The social power of algorithms', *Information, Communication and Society,* 20(1), 1-13.

Beer, D. (2009) 'Power through the algorithm? Participatory web cultures and the technological unconscious', *New Media & Society,* 11(16), 985–1002.

Berners-Lee, T., Hendle, J., & Lassila, O. (2001) 'The semantic web', *Scientific American,* 285(5), 34-43.

Bogost, I. (2007) *Persuasive games: The expressive power of videogames*. Cambridge: MIT Press.

Bogost, I. (2011) *How to do things with video games*. Minneapolis: University of Minneapolis Press.

Bourdieu, P. & Passeron, J.-C. (1990) *Reproduction in education, society and culture*. New York: Sage.

Bowker C. & Star, L. (1999) *Sorting things out: Classification and its consequences*. Cambridge: MIT Press.

Bucher, T. (2017) 'The algorithmic imaginary: Exploring the ordinary affects of Facebook algorithms', *Information, Communication and Society,* 20(1), 30–44.

Bucher, T. (2018) *If… then: Algorithmic power and politics*. Oxford: Oxford University Press.

Buckingham, D. (2007) 'Digital media literacies: Rethinking media education in the age of the Internet', *Research in Comparative and International Education,* 2(1), 43-55.

Cheney-Lippold, J. (2011) 'A new algorithmic identity: Soft biopolitics and the modulation of control', *Theory, Culture & Society*, 28(6), 164–181.

Citton, Y. (2017) *The Ecology of attention*. Cambridge: Polity.

Clarke R. (1988) 'Information technology and dataveillance', *Communications of the ACM,* 31(5), 498-512.

Clarke R. (1994) 'The digital persona and its application to data surveillance', *Information Society,* 10(2), 77-92.

Cope, B, & Kalantzis, M. (2016) 'Big data comes to school: Implications for learning, assessment and research', *AERA Open,* 2(2), 1–19.

Crawford, K. (2021) *Atlas of AI: Power, politics, and the planetary costs of artificial intelligence.* New Haven: Yale University Press.

Dasgupta, S. and Hill, B. (2021) Designing for critical algorithmic literacies. Available at: https://wip.mitpress.mit.edu/pub/designing-for-critical-algorithmic-literacies/release/1 (Accessed: 21 April 2022).

de Certeau, M. (1988) *The Practice of everyday life*. Los Angeles: University of California Press.

Flanagan, M. (2009) *Critical play:* R*adical game design*. Cambridge: MIT Press.

Flanagan M. & Nissenbaum, H. (2014) *Values at play in digital games*. Cambridge: MIT Press.

Foucault, M. (1995) *Discipline and punish: The birth of the prison*. New York: Vintage.

Galloway, A. (2004) *Protocol: How control exists after decentralization*. Cambridge: MIT Press.

Galloway, A. (2006) *Gaming: Essays on algorithmic culture*. Minneapolis: University of Minnesota Press.

Gee, J. (2003) *What video games have to teach us about learning and literacy*. London: Palgrave.

Giroux, H. (1983) 'Theories of reproduction and resistance in the new sociology of education: A critical analysis', *Harvard Educational Review,* 53(3), 257–293.

Goering, C. & Thomas, P. (2018) *Critical media literacy and fake news in post-truth America.* Leiden: Brill.

Hall, L. & Clapton, W. (2021) 'Programming the machine: gender, race, sexuality, AI, and the construction of credibility and deceit at the border', *Internet Policy Review*, 10(4), 1-23.

Hall, M., van der Maaten, L., Gustafson, L., Jones, M., and Adcock, A. (2022) 'A Systematic study of bias amplification', *Arxiv.org,* https://arxiv.org/abs/2201.11706 (Accessed: 19 September 2022).

Hogan, B. (2010) 'The Presentation of self in the age of social media: Distinguishing performances and exhibitions online', *Bulletin of Science Technology & Society,* 30(6), 377-386.

Janks, H. (2018) 'Texts, identities, and ethics: Critical literacy in a post-truth world', *Journal of Adolescent & Adult Literacy,* 62(1), 95–99.

Jenkins, H., Clinton, K., Purushotma, R., Robison, A. & Weigel, M. (2006) *Confronting the challenges of participatory culture: Media education for the 21st century.* MacArthur Foundation.

Jones, R. (2020) 'The rise of the pragmatic web: Implications for rethinking meaning and interaction'. In Tagg, C. and Evans, M. (eds.), *Historicising the digital: English language practices in new and old media* (pp. 17-37). Berlin: de Gruyter Mouton.

Kafai, Y., Proctor, C., & Lui, D. (2020) 'From theory bias to theory dialogue: Embracing cognitive, situated, and critical framings of computational thinking in K-12 CS education', *ACM Inroads,* 11(1), 44-53.

Kellner, D., & Share, J. (2007) Critical media literacy, democracy, and the reconstruction of education. In D. Macedo & S. R. Steinberg (Eds.), *Media literacy: A reader* (pp. 3-23). New York: Peter Lang.

Kitchens, B., Johnson, S., & Gray, P. (2020) 'Understanding echo chambers and filter bubbles: The impact of social medial on diversification and partisan shifts in news consumptions', *MIS Quarterly,* 44(4), 1619-1649.

Kitchin, R. (2017) 'Thinking critically about and researching algorithms', *Information, Communication & Society*, 20(1), 14–29.

Koenig, A. (2020) 'The Algorithms know me and I know them: Using student journals to uncover algorithmic literacy awareness', *Computers and Composition*, 58, 1-14.

Latour, B. (1996) 'On actor-network theory: A few clarifications', *Soziale Welt*, 47(4), 369–381.

Law, J. (1990) 'Introduction: Monsters, machines and sociotechnical', *The Sociological Review*, 38(1), 1-23.

Leander K. & Buriss, L. (2020) 'Critical literacy for a posthuman world: When people read, and become, with machines', *British Journal of Educational Technology,* 51(1), 1-15.

Lee, C., & Soep, E. (2016) 'None but ourselves can free our minds: Critical computational literacy as a pedagogy of resistance', *Equity and Excellence in Education,* 49(4), 480–492.

Lim, M. (2020) 'Algorithmic enclaves: Affective politics and algorithms in the neoliberal social media landscape'. In M. Boler & E. Davis (eds.), *Affective Politics of Digital Media: Propaganda by Other Means* (pp. 186-203). London: Routledge.

Lotherington, H., Thumlert, K., Boreland, T., & Tomin, B. (2021) 'Redesigning for mobile plurilingual futures', *OLBI Journal,* 11, 141-172.

Longborg, S. & Kapsch, P. H. (2020) 'Decoding algorithms', *Media, Culture and Society*, 42(5) 745–761.

Luke, A. (2012) 'Critical literacy: Foundational notes', *Theory into Practice,* 51(1), 4–11.

Mann, S., Nolan, J., & Wellman, B. (2003) 'Sousveillance: Inventing and using wearable computing devices for data collection in surveillance environments', *Surveillance & Society,* 1(3), 331–355.

Manovich, L. (2019) *AI aesthetics*. Moscow: Strelka.

Markham, A. N. (2020) 'Taking data literacy to the Streets: Critical pedagogy in the public sphere', *Qualitative Inquiry*, 26(2), 227–237.

Mertala, P. (2021) 'The pedagogy of multiliteracies as a code breaker: A suggestion for a transversal approach to computing education in basic education', *British Journal of Educational Technology*, 52(6), 2227-2241.

Moulthrop, S. (1994) 'Rhizome and resistance: Hypertext and the dream of a new culture', in George P. Landow, (ed.) *Hyper/Text/Theory* (pp. 299-322). Baltimore: John Hopkins Press.

Munir, H., Vogel, B., & Jacobsson, A. (2022) 'Artificial intelligence and machine learning approaches in digital education: A Systematic revision', *Information*, 13(4), 1-26.

Murray J. (1997) *Hamlet on the Holodeck: The future of narrative in cyberspace*. New York: The Free Press.

New London Group (NLG). (1996) 'A pedagogy of multiliteracies: Designing social futures', *Harvard Educational Review,* 66(1), 60–92.

Noble, S. (2018) *Algorithms of oppression: How search engines reinforce racism*. New York: New York University Press.

Nolan, J., & McBride, M. (2014) 'Beyond gamification: Reconceptualizing game-based learning in early childhood environments', *Information, Communication & Society,* 17(5), 594–608.

Nolan, J., Raynes-Goldie, K., & McBride, M. (2011) 'The stranger danger: Exploring surveillance, autonomy, and privacy in children's use of social media', *Journal of Childhood Studies*, 36(2), 24–32.

Obar, J. A. & Oeldorf-Hirsch, A. (2020) 'The biggest lie on the Internet: Ignoring the privacy policies and terms of service policies of social networking services', *Information, Communication & Society,* 2*3*(1), 128-147.

Obar, J. A. (2021) 'Source triangulation skills and the future of digital inclusion: How information literacy policy can address misinformation and disinformation challenges', *Yale Law School Information Society Project*: Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3828152 (Assessed April 14, 2022).

O'Neil, C. (2017) *Weapons of math destruction: How big data increases inequality and threatens democracy*. New York: Penguin Books.

Poster, M. (1995) *The Second Media Age*. Cambridge: Polity.

Pronzato, R. (2021) 'Critical pedagogy as a practice of resistance to algorithms', *The 22nd Annual Conference of the Association of Internet Researchers*.

Salter, A. & Moulthrop, S. (2021) *Twining: Critical and creative approaches to hypertext narratives.* Amherst: Amherst College Press.

Shew, A. (2020) 'Ableism, technoableism, and future AI', *IEEE Technology and Society Magazine,* 39(1), 40-85.

Shortt, M., Tilak, S., Kuznetcova, I, Martens, B. & Babatunde, A. (2021) 'Gamification in mobile-assisted language learning: A systematic review of Duolingo literature from public release of 2012 to early 2020', *Computer Assisted Language Learning*, 1-38.

Smith K. & Parker, L. (2021) 'Reconfiguring literacies in the age of misinformation and disinformation', *Journal of Language and Literacy Education,* 17(2), 1-27.

Stark, B. Stegmann, D., Magin, M. & Jürgens, P. (2020) *Are algorithms a threat to democracy? The rise of intermediaries: A challenge for public discourse.* Algorithm Watch.

Stockman, C. & Nottingham, E. (2022) 'Surveillance capitalism in schools: What's the problem?', *Digital Culture and Education,* 14(1), 1–15.

Striphas, T., (2015) 'Algorithmic culture', *European Journal of Cultural Studies,* 18(4-5), 395–412.

Suchman, L. (1987) *Plans and situated actions: The problem of human-machine communication.* Cambridge: Cambridge University Press.

Swart, J. (2020) 'Tactics of algorithmic literacy: How young people understand and negotiate algorithmic news selection', paper presented at *AoIR 2020: The 21th Annual Conference of the Association of Internet Researcher*s.

Selwyn, N. (2019) 'What's the problem with learning analytics?', *Journal of Learning Analytics*, 6(3), 11–19.

Toncic, J. (2020) 'Teachers, AI grammar checkers, and the newest literacies: Emending writing pedagogy and assessment', *Digital Culture & Education,* 12(1), 26–51.

Thumlert, K., de Castell, S. & Jenson, J. (2015) 'Short cuts and extended techniques: Rethinking relations between technology and educational theory', *Educational Philosophy and Theory*, 47(8), 786-803.

Thumlert, K., Smith, B., Hébert, C., & Tomin. B. (2020) 'Space is the place: Pre-service teachers re/map cartographic landscapes', *Digital Culture & Education,* 12(1), 52–71.

Thumlert, K. de Castell & Jenson (2018) 'Learning through game design: A production pedagogy', *ECGBL 2018 12th European Conference on Game-Based Learning.* Reading (UK): ACPI.

Thumlert, K. de Castell, S., & Jenson, J. (accepted paper) 'Toward a more resilient democracy: opportunities for digital game design pedagogies', The IAFOR International Conference on Education (IICE2023). January 3-8, 2023.

Mann, S., Nolan, J., & Wellman, B. (2003) 'Sousveillance: Inventing and using wearable computing devices for data collection in surveillance environments', *Surveillance & Society*, 1(3), 331-335.

Williamson B. (2018) 'Who owns educational theory? Big data, algorithms and the expert power of education data science', *E-Learning and Digital Media,* 14(3), 105-122.

Willson, M. (2017) 'Algorithms (and the) everyday', *Information, Communication & Society*, 20(1), 137-150.

Willson M., & Kinder-Kurlanda, K. (2021) 'Social gamers' everyday (in)visibility tactics: playing within programmed constraints', *Information, Communication & Society,* 24(1), 134-149.

Woolgar S. (1990) 'Configuring the user: The case of usability trials', *Sociological Review*, 38(1), 58-99.

Wu, T. (2017) *The Attention merchants: The epic scramble to get inside our heads.* New York: Vintage

Yeung, K. (2017) 'Hypernudge: Big data as a mode of regulation by design', *Information, Communication & Society,* 20(1), 118-136.

Zuboff, S. (1988) *In the age of the smart Machine: The future of work and power*. New York: Basic Books.

Zuboff, S. (2017) *The Age of surveillance capitalism: The fight for a human future at the new frontier of power*. New York: Public Affairs Books.