

Bridging Knowledge Gaps: Advancing Cybersecurity Education via Absorptive Capacity and Collaboration

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Abstract: This work, based on my dissertation (Esmaili, 2024), investigates the growing knowledge gap between vocational cybersecurity education and the cybersecurity industry, driven by rapid technological advancements and the increasing demand for skilled professionals. This gap challenges educators' ability to deliver current and relevant training, limiting their capacity to prepare students for the dynamic and evolving needs of the cybersecurity field (Yusuf, 2024). Absorptive capacity (ACAP)—the ability to recognize, assimilate, and apply external knowledge—serves as the conceptual framework to address this challenge. By integrating perspectives on absorptive capacity, knowledge creation, and collaboration, this study examines mechanisms that enhance effective learning within partnerships between vocational education programs and the cybersecurity industry. This research employs an action research methodology, structured across four iterative cycles: i) establishing partnerships, ii) implementing collaborative learning environments, iii) engaging educators as active learners, and iv) developing an innovation lab for knowledge co-creation. Data were collected through semi-structured interviews with educators, students, and cybersecurity professionals, and analyzed using open and axial coding to identify key themes and mechanisms. The findings show that trust-building, participatory decision-making, informal communication, and cross-functional activities are essential for strengthening educators' ability to integrate new knowledge. Educators' active involvement as learners proved crucial in bridging the knowledge gap and aligning curricula with the practical demands of the cybersecurity industry. The innovation lab emerged as a platform for knowledge co-creation, fostering meaningful collaboration between students, educators, and professionals. This research contributes to the literature by addressing gaps in ACAP implementation and emphasizing collaborative approaches to industry-education alignment. Key recommendations include promoting continuous professional development for educators, implementing co-creative learning models, and aligning cybersecurity education with industry needs to ensure future-proof training programs.

Keywords: Cybersecurity education, Absorptive capacity, Industry-education collaboration, Knowledge development, Action research

1. Introduction

Within the cybersecurity vocational program at the Amsterdam University of Applied Sciences (AUAS), an increasing knowledge gap between cybersecurity educators and the professional cybersecurity field, has been noted. Technological advancements occur at such a rapid pace that the industry continually demands new skills from educators. However, the heavy workload of educators often limits opportunities for ongoing professional development. As a result, educators often teach skills that are not fully aligned with current industry developments (Yusuf, 2024).

Collaboration between vocational education and the business sector is widely recognized as essential. However, in practice, such collaboration is neither automatic nor easily organized. This raises the critical question: how can collaboration between cybersecurity vocational education and the cybersecurity professional field be developed to ensure that the knowledge of teachers, students, and professionals remains current?

This work examines the issue of maintaining current knowledge in cybersecurity vocational education and the professional field through the lens of ACAP. The rapidly changing nature of cybersecurity necessitates a high degree of absorptive capacity. With the ongoing threat of cyberattacks, professionals must be equipped to apply up-to-date knowledge in practice.

2. Theoretical Framework

ACAP as introduced by Cohen and Levinthal (1990), describes the ability of an organization or individual to recognize, assimilate, and apply external knowledge. Since its introduction, the concept has evolved, encompassing perspectives such as learning, innovation, managerial cognition, knowledge-based organizational theory, dynamic capabilities, and co-evolution (Volberda, Foss & Lyles, 2010). A critical distinction in the literature is the focus on absorptive capacity at the organizational versus individual level.

Organizational absorptive capacity refers to an organization's ability to assimilate and integrate external knowledge, such as new technologies, into existing knowledge and activities. Organizations with high absorptive capacity can adapt to environmental changes (Zahra & George, 2002).

Individual absorptive capacity, by contrast, refers to the ability of an individual to assimilate, understand, and effectively apply new knowledge. This capacity involves learning from diverse sources, including education, training, experience, and interactions with the external partners (Volberda et al., 2010). This work focuses on exploring and analyzing this concept in depth.

Volberda et al. (2010) identify five key factors that influence the absorptive capacity of individuals within organizations and emphasize that these areas warrant further research due to limited existing studies: the role of training and development activities in enhancing individual capabilities, the mechanisms through which leadership fosters knowledge sharing, the impact of organizational structures and informal networks on knowledge absorption, the processes by which individuals acquire and integrate knowledge in inter-organizational collaborations, and the design of adaptive processes and routines to maximize knowledge application in dynamic environments.

These scholars further argue that these under-researched areas present important opportunities for advancing our understanding of how individuals within organizations can enhance their absorptive capacity. On the other hand, there is a noticeable lack of studies within the ACAP theory that focus on designing interventions aimed at improving the ACAP of individuals within organizations (Volberda et al., 2010; Sakhdari, 2016; Apriliyanti & Alon, 2017). This research, which is based on intervention design, contributes to addressing this gap in the literature.

The research question is:

What mechanisms in the collaboration between AUAS and the business sector contribute to absorptive capacity at the organizational and individual levels?

3. Methodology

The action research methodology was chosen based on Susman and Evered (1978) and elaborated by Davison, Martinsons and Kock (2004) and Van Lieshout, Jacobs and Cardiff (2021). This approach aligns with the study's focus on collaboration and co-creation.

A literature review identified mechanisms (see Tables 1–3) relevant to the research context, synthesized into interventions. Semi-structured interviews with teachers, students, and professionals evaluated these interventions. Data analysis employed open, axial, and selective coding. The results guided the decision on whether additional action research cycles were needed and how they should be carried out. Consequently, four successive action research cycles were designed:

1. Developing collaboration between AUAS, and ICT companies.
2. Establishing decentralized teams at several ICT companies where students, a teacher, and a company professional collaborate to solve a specific problem, with the teacher acting as a process facilitator.
3. Continuing decentralized team development at ICT companies but with both the teacher and student engaging as learners.
4. Creating centralized teams in an innovation lab at the Amsterdam University of Applied Sciences where students, a teacher, and a company professional collaborate to address a joint issue, with both the teacher and student engaging as learners.

The researcher and the participants were jointly responsible for and co-creators of the process and the interpretation of the research results. The researcher assumed three different roles: researcher, project leader, and content expert.

4. Literature Review

The literature review by Volberda et al. (2010) served as a starting point for identifying mechanisms to enhance individual absorptive capacity. A Scopus search using the keyword "ACAP" for English articles and reviews (2011–2020) yielded 106 relevant studies, with 19 focusing on micro-foundations, cross-functional activities, and organizational and managerial characteristics. Since absorptive capacity theory emphasizes the importance of acquiring knowledge from external partners but lacks structure for this process, insights from

knowledge creation theory (Nonaka & Takeuchi, 2000) and collaboration theory (Kaats & Opheij, 2012) were used to bridge this gap.

5. Identified Mechanisms

The research identifies 41 mechanisms from absorptive capacity, knowledge creation, and inter-organizational collaboration (Tables 1–3), which were used throughout the study.

Table 1: Absorptive Capacity Development Mechanisms

Authors	Mechanisms
Tortoriello (2015)	1. The role of the gatekeeper is assigned to participants with extensive internal and external networks.
Pertusa-Ortega, Zaragoza-Sáez and Claver-Cortés (2010); Ali, Musawir and Ali (2018)	2. The organizational structure is built on knowledge specialization, low formalization, decentralization, and integration.
Darawong (2015)	3. Social interactions are structured to promote informal cross-functional communication within and across teams.
Da Mota Pedrosa, Välling and Boyd (2013)	4. Managers are identified who can source and integrate relevant external knowledge into the organization's knowledge base.
Pitz, Intindola, Adler, Rogers and Gard (2019); Jansen, Van den Bosch and Volberda (2006)	5. A process is initiated to foster shared interest in knowledge acquisition and exploitation among participants. 6. Participants engage in decision-making and cross-functional activities, strengthening trust and goal interdependence.
Ojo and Raman (2017)	7. Teams are assembled based on individuals' knowledge relevant to specific problems. 8. The importance of participants' learning-oriented roles within project teams is emphasized.
Ojo et al. (2017); Yang and Tsai (2019)	9. Individual learning motivation is encouraged, with a focus on integration and shared understanding in teams.
Ojo et al. (2017)	10. Enhance individual learning, foster team collaboration, and align shared mental models to effectively recognize, assimilate, and apply knowledge in teams.
Löwik, Kraaijenbrink and Groen (2016)	11. Optimal knowledge sharing occurs in teams of 4 to 7 members.
Cappellari, Welter and Hermes (2019)	12. Betas engage in dialogues with customers and companies at the product level, making them key participants in the teams.
Kazadi, Lievens and Maher, (2016); Dahlin, Moilanen, Østbye and Pesämaa (2020)	13. Co-creation processes are organized with companies to collaboratively develop knowledge. 14. Training sessions are organized for students, teachers, and professionals in collaboration.
Lewin, Massini and Peeters (2011)	15. Knowledge-sharing activities include external routines like informal interactions with companies and partner workshops, and internal routines like kick-off and wrap-up meetings, committees for knowledge assessment, and reflective assessments with feedback.
Darwish, Zeng, Rezaei Zadeh and Haak-Saheem (2018)	16. Transformational leadership is essential in learning environments and organizations to foster a learning culture.

Table 2: Knowledge development mechanisms

Authors	SECI model	Mechanisms
Nonaka et al. (2000); Darawong (2015); Kazadi et al. (2016); Ojo et al. (2017); Cappellari et al.	Socialization	17. A collaborative learning environment is established to promote informal cross-functional communication through organized social interaction and cross-functional activities among team members and teams.
		18. Social interaction, face-to-face contact, collaboration, sharing experiences, and integrating diverse expertise from both customers and suppliers are key components.

Authors	SECI model	Mechanisms
(2019); Dahlin et al. (2020)		19. Teams are formed based on individuals' knowledge of specific issues, emphasizing the importance of every participant acting as a learner within the project team.
		20. Teams working on different products enhance ACAP through knowledge-sharing cross-functional communication. Optimal team size for knowledge-sharing is maintained between 4 and 7 members.
		21. Real-world issues presented by actual clients reinforce credibility. Co-creation with companies is organized to collaboratively generate knowledge.
		22. A learning community is fostered, involving experts and professionals. Respect, equality, and curiosity are promoted to enhance learning, ensuring inclusivity for all participants.
		23. Ownership of the learning process is emphasized, with individuals responsible for their learning, contributing to and benefiting from knowledge sharing.
		24. Teams are formed with diversity in mind, collaborating with educators and professionals. After evaluations by educators, students, and professionals, interventions are designed to improve the process.
		25. Assignments are presented by professionals and educators, offering student teams the opportunity to choose from these assignments to develop their talents.
Nonaka et al. (2000); Tynjälä, Häkkinen and Hämäläinen (2015)	Externalization	26. Based on a reflective report, "lessons learned" are shared among participants. A dialogue session is organized where participants provide feed-up, feedback, and feed-forward to each other. Students present their work and receive feedback from educators and professionals.
		27. Assessments are organized where educators, professionals, and students engage in dialogue to make implicit knowledge explicit.
Nonaka et al. (2000); Ali et al. (2018)	Combination	28. Students, educators, and the business sector combine new knowledge with existing knowledge (formalization). Additional formal time is allocated for educators to enrich courses with the newly acquired knowledge.
		29. An (online) space is created where new knowledge is recorded and subsequently added to existing knowledge.
		30. The developed knowledge is documented and utilized by educators in their teaching content. Businesses can incorporate it into new or existing products.
Nonaka et al. (2000); Hernández-Perlines, Moreno-García and Yáñez-Araque (2017)	Internalization	31. Solving tasks through 'learning-by-doing' helps participants internalize existing knowledge.
		32. Training sessions are organized, which have a positive effect on ACAP.

Table 3: Inter-organizational collaboration mechanisms

Authors	Mechanisms
Benson and Ziedonis (2009); Rothaermel and Alexandre (2009)	33. Collaboration functions as a learning platform enabling the discovery, generation, and application of new knowledge through participant interaction.
	34. Dynamic collaboration is maintained by adding new companies to the network, ensuring adaptability.
	35. Collaboration involves mutual influence and negotiation, creating new norms and values by abandoning established rules to build a shared structure.
Kaats and Opheij (2012);	36. Companies and educators join collaborations to fulfill interests through shared knowledge development, positioning this as the common ambition.
	37. Mission: Defines the purpose of the collaboration. Goals: Sets clear objectives for the partnership. Strategy: Details how the goals will be achieved. These elements establish the framework for the "new organization" formed through the collaboration.
	38. Interests of all network parties are integrated to establish a shared interest.
	39. Collaboration content is discussed to reduce misunderstandings and achieve meaningful

Authors	Mechanisms
Boonstra (2018)	content development by clarifying the purpose of the partnership.
Darwish et al. (2018)	40. Participants are approached for knowledge sharing based on transformational leadership, prioritizing their interests.
Proven and Kenis (2008)	41. Self-Regulating Collaboration: Clear agreements on objectives ("what") provide structure while allowing flexibility in methods ("how"), fostering alignment and sustained engagement.

Sixteen mechanisms have been identified that influence absorptive capacity at both organizational and individual levels (see Table 1). Active involvement of employees in cross-functional activities and decision-making processes has been shown to positively impact absorptive capacity. Initiating partnerships and sharing and developing knowledge with external partners are recognized as substantial factors promoting absorptive capacity. However, the literature does not provide insights into how collaboration with external partners can be practically achieved. It also offers little insight into how knowledge is shared and developed in partnerships.

Additionally, there are nine mechanisms identified for collaboration and sixteen for knowledge development (see Tables 2 and 3).

The total forty-one mechanisms show a wide variation in subjects, impact on ACAP, and level (individual and organizational). There is a significant difference in nature and perspective among these mechanisms. They have been independently studied with little interrelation. These mechanisms could not be directly translated into practice. However, they inspired the design of the action research cycles by clustering relevant mechanisms.

6. Four Action Research Cycles

For action research cycle 1, eight relevant mechanisms were identified that substantially contribute to the development of partnerships. These mechanisms were clustered and summarized into Mechanism A: *A collaboration of organizations aimed at increasing ACAP requires a shared interest and ambition for knowledge development among the participating organizations.*

For action research cycle 2, eight relevant mechanisms were identified that contribute to the development of collaborative learning environments within companies, where knowledge is shared and developed. These mechanisms were also clustered and summarized into Mechanism B: *Social interaction and cross-functional communication between participants working on a current issue enhance the knowledge development of participants, provided they are learners, and the team size ranges between four and seven members.*

For action research cycle 3, two relevant mechanisms were identified that promote the creation of collaborative learning environments within companies, where all participants take on a learning role. These two mechanisms were summarized into Mechanism C: *The individual capacity for knowledge development increases when a participant takes part in a collaborative learning environment as a learner.*

For action research cycle 4, fourteen relevant mechanisms were identified that contribute to the development of collaborative learning environments, centrally located in an innovation lab. These mechanisms were clustered into Mechanism D: *To further promote ACAP, students are grouped into teams based on their backgrounds. A kick-off event is organized to introduce participants to the clients and issues. To achieve cross-functional communication between teams, the teams work in the lab. An assessment is organized so participants can share and combine the developed knowledge with existing knowledge through dialogue.*

These summarized mechanisms A, B, C, and D were translated into concrete interventions and the design of the respective action research cycles.

7. Evaluation of the Research Cycles

According to the literature review, evaluation (Boonstra, 2018), organization (Proven et al, 2008), and leadership (Darwish et al., 2018) play a dominant role in promoting ACAP at both the organizational and individual levels.

For the evaluation of the action research cycles, four relevant mechanisms were identified and clustered into the Evaluation Mechanism: *By evaluating the collaborative learning environments, the shared interest and ambition are reaffirmed. This reduces misunderstandings between participants and clarifies and sharpens the goal of the collaboration. Participants articulate the added value of the current collaborative learning*

environment as well as areas for improvement. This process leads to a dynamic change over time in the collaborative learning environment.

For organizing collaborative learning environments, two relevant mechanisms were selected, clustered, and summarized into the Organization Mechanism: *The organizational structure of the innovation lab is content-driven without a hierarchical line. Based on current issues, teams were formed to collaborate. This organization represents a hybrid structure balancing the process-driven logic of vocational education and the result-driven logic of the professional field.*

For leadership of the process, five relevant mechanisms were identified and summarized into one mechanism, known as the Leadership Mechanism: *The project leader approaches participants to engage in a knowledge-sharing process based on their own interests. The interest of the participants is crucial for their participation. A manager with subject matter expertise and a broad internal network can present relevant new knowledge, including training, from the external environment to the appropriate employees to expand their knowledge base. A gatekeeper with a broad network is beneficial for the knowledge flow into the collaboration.*

Evaluation, organization, and leadership proved to be of great importance in all stages of the various successive 4 cycles of this process (Esmaili, 2024).

The evaluation mechanism was used to assess an action research cycle retrospectively, leading to the determination of necessary actions for the next research cycle to further develop the collaboration. The organization mechanism was used to make the organizational structure content-driven, meaning teams were formed based on current issues. This organization was structured to collaboratively solve current issues and develop knowledge for both individuals and the collaboration as a whole. The leadership mechanism ensured that the claims, concerns, and issues (CCI) of students, educators, and professionals were openly expressed and discussed.

8. Discussion

Action research cycle 1, on studying the mechanisms that contribute to the development of a collaboration of organizations aimed at joint knowledge development, it became clear that Mechanism A was merely the start of the process. This action research cycle demonstrated that the project leader's role was crucial in terms of the leadership mechanism described above. This leadership intervention developed trust among companies.

This proved to be crucial for the collaboration. A sense of mutual confidence allowed companies to share their actual claims, concerns, and issues with the project leader, which then enabled organizational adjustments. Initially, the companies intended to establish legal agreements for intellectual property on a project-by-project basis. However, this foundation of reliability enabled them to agree to handle knowledge-sharing arrangements for each assignment individually, fostering a more flexible and cooperative approach.

Trust among participants proved to be a crucial mechanism that facilitated open communication and collaboration. This aspect requires further research within the context of absorptive capacity (ACAP). Both the roles of trust and leadership remain underexplored in the ACAP literature, despite their significant influence on fostering collaboration and adaptability.

The following factors emerged from the action research cycles as important in developing a collaboration of organizations aimed at joined knowledge development:

- Perceived urgency: Collaboration between organizations in the field of cybersecurity was promoted by the combination of a rapidly changing knowledge domain and a tight labor market. For the Amsterdam University of Applied Sciences (AUAS), this collaboration was essential as they aimed to develop a bachelor's program in cybersecurity.
- Importance for companies: Companies saw the collaboration as an opportunity to connect with students during their education, which was advantageous given the tight labor market.
- Mutual dependency: The involved parties found a shared interest and ambition more quickly due to their mutual dependency. ICT programs needed input from companies to develop current and relevant cybersecurity programs, and companies needed graduates with an up-to-date education.

In practice, each action research cycle required additional interventions to foster knowledge sharing and development. The findings from the four action research cycles revealed that absorptive capacity at both the organizational and individual levels was influenced by various mechanisms. All 41 mechanisms identified in the literature played a role in enhancing the ACAP, although their precise impact was not always clear in practice.

The effectiveness of these mechanisms varied across the different cycles. Furthermore, each new cycle introduced an additional mechanism, resulting in all mechanisms being active by the fourth cycle.

The fourth cycle emphasized the importance of an appropriate organizational structure. The innovation lab had no hierarchical structure but worked based on current issues. This promoted collaboration and balanced the process-oriented logic of education with the result-oriented logic of the professional field. This led to teachers valuing both the process and the outcome, while professionals gained more attention to the process. These approaches brought the perspectives of teachers and professionals closer together.

A collaborative learning environment emerged, where teachers, students, and professionals worked together on current issues. This promoted the development of a shared interest among all participants, stimulating knowledge exchange and narrowing the gap between teachers and professionals. This allowed teachers to update their knowledge and train students with current knowledge.

Evaluations were essential in all four cycles. Through evaluations, the shared interest and ambition were reaffirmed, reducing misunderstandings. Additionally, evaluations led to concrete adjustments and interventions to promote ACAP, ensuring continuous development of the collaborative learning environment.

Mechanisms such as social interaction, cross-functional collaboration, knowledge sharing, and involving learners in current issues correspond to the socialization process of the SECI model. The use of assessments to externalize knowledge aligns with the externalization process, while the application of newly developed knowledge in education or products reflects the combination process. The integration of this knowledge into a knowledge repository fits within the internalization process.

Notably, the SECI model does not explicitly address the role of evaluation and leadership, while this research reveals that these factors, along with trust-building, are crucial for both ACAP and knowledge development. This study highlights the importance of a knowledge-sharing process for strengthening ACAP, addressing a knowledge gap in the ACAP literature (Volberda et al., 2010). Furthermore, the knowledge creation theory of Nonaka et al. (2000) provides a practical framework for structuring such processes, emphasizing evaluation, leadership, and trust as critical success factors.

The outcome and significance of the four action research cycles were the creation of a new bachelor's program in cybersecurity at the AUAS, where students collaborate with teachers and professionals to address current issues. Together, they develop new products and services for companies. The knowledge gained in the action research cycles is embedded in the program, fostering a proactive mindset among students. They recognize their importance within the program; when they are absent, they are missed, and their return is eagerly anticipated. This collaboration emphasizes that everyone involved is both essential and indispensable.

The first cohort of this program graduated in June 2021, and the graduation ceremony highlighted an unprecedented number of students graduating cum laude. This was a unique achievement for the ICT programs at the AUAS and was attributed to the students' enthusiasm for engaging with teachers and professionals. Consequently, absenteeism and sick leave were virtually nonexistent.

This program has been recognized as innovative by the Dutch-Flemish Accreditation Organization (NVAO) due to its strong collaboration with the business sector. Media outlets have also highlighted the program's unique approach. For instance, Parool published a full-page article on June 1, 2021, while the television program *EenVandaag* featured the program on August 2, 2021, praising its partnership with companies.

9. Conclusion

The research question addressed is: What mechanisms in the collaboration between AUAS and the business sector contribute to absorptive capacity at the organizational and individual levels?

The findings demonstrate that various mechanisms play a crucial role in enhancing absorptive capacity at both levels. Based on a literature study, a total of 41 mechanisms were identified, and the results of the four action research cycles strongly align with the SECI model of Nonaka et al. (2000).

In answering the research question, this research emphasizes the potential of networks between companies and educational institutions to enhance absorptive capacity and foster knowledge development for further research and practice. It demonstrates that insights from this field, along with knowledge development, and collaboration literature provide a valuable repertoire of interventions for strengthening such networks. Process characteristics such as social interaction, experience sharing, team performance, coaching, and information exchange significantly contribute to this development. Although absorptive capacity theory was

initially regarded as foundational for collaborations in knowledge development, it primarily served as a starting point within the action research cycles. Throughout these cycles, evaluation, leadership, and trust emerged as pivotal factors for achieving progress.

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