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Systematic Review of CLIL in Computer Science: Past, Present, and Future — with a Special Focus on Using ICT

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Revisión sistemática de AICLE en informática: pasado, presente y futuro, con un enfoque especial en el uso de las TIC

Revisão sistemática do CLIL em informática: passado, presente e futuro, com foco especial no uso das TIC

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ABSTRACT. Computer science is regarded one of the subjects best suited for teaching with ICT-supported CLIL, as the English language is the lingua franca of computing, and the computer science classroom is an ideal place to apply digital technologies. This paper aims to explore the role of content and language integrated learning (CLIL) in the teaching and learning of computer science in English – focusing especially on using information and communication technology (ICT). For this purpose, a systematic literature review based on the PRISMA protocol was carried out. A total of 31 documents published in the period 2011–2021 on CLIL in computer science and ICT in the CLIL environment were analysed. In this article, first, the advantages of using CLIL in computer science will be discussed, followed by illustrating the benefits and challenges of applying ICT in CLIL lessons. Finally, trends in research on technology enhanced CLIL will be presented, outlining existing findings as well as identifying research gaps in the field. The most important shortcomings and difficulties outlined in the related literature are the limited research on both CLIL and ICT supported CLIL in the subject of computer science, the inconsistent terminology for using ICT in CLIL, and the need in CLIL teacher training courses for the effective use of digital technologies. Therefore, the findings of this paper identify a variety of future research agendas in order to increase the effective, ICT-supported CLIL in the subject of computer science.

Keywords (Source: Unesco Thesaurus): Content and language integrated learning (CLIL); computer science; Information and Communication Technologies (ICT); technology; bilingual education; technology-enhanced CLIL; interdisciplinary approach; systematic review.

RESUMEN. La informática se considera una de las materias más adecuadas para la enseñanza con AICLE apoyado por las TIC, ya que el inglés es la lengua franca de la informática y el aula de informática es un lugar ideal para aplicar las tecnologías digitales. Este documento busca explorar el papel del aprendizaje integrado de contenido y lenguaje (AICLE) en la enseñanza y el aprendizaje de informática en inglés, centrándose especialmente en el uso de las tecnologías de la información y la comunicación (TIC). Para tales fines, se realizó una revisión sistemática de la literatura basada en el protocolo PRISMA. Se analizaron un total de 31 documentos publicados durante el periodo 2011-2021 sobre AICLE en informática y TIC en el entorno AICLE. En el presente artículo se discuten, en principio, las ventajas de usar AICLE en informática y, luego, se ilustran los beneficios y desafíos de aplicar las TIC en las lecciones de AICLE. Finalmente, se presentarán las tendencias en investigación sobre AICLE mejorado con tecnología, destacando los hallazgos existentes e identificando las lagunas en la investigación en el campo. Las deficiencias y dificultades más importantes que se describen en la literatura relacionada son la investigación limitada sobre AICLE y AICLE con apoyo de las TIC en la materia de informática, la terminología inconsistente para el uso de TIC en AICLE y la necesidad de cursos de formación de profesores de AICLE para el uso efectivo de tecnologías digitales. Por lo tanto, los hallazgos de este artículo identifican una variedad de futuros planes de investigación con el fin de aumentar el AICLE eficaz y apoyado por las TIC en el campo de la informática.

Palabras clave (Fuente: Thesaurus de la Unesco): Aprendizaje integrado de contenidos y lenguas (AICLE); informática; Tecnologías de la Información y la Comunicación (TIC); tecnología; educación bilingüe; AICLE mejorado con tecnología; enfoque interdisciplinario; revisión sistemática.

RESUMO. A informática é considerada uma das disciplinas mais adequadas para o ensino CLIL apoiado em TIC, pois o inglês é a língua franca da ciência da informática e a sala de informática é o local ideal para aplicar as tecnologias digitais. Este documento procura explorar o papel da aprendizagem integrada de conteúdo e linguagem (CLIL) no ensino e aprendizagem de informática em inglês, com foco particular no uso de tecnologias de informação e comunicação (TIC). Para tanto, foi realizada uma revisão sistemática da literatura baseada no protocolo PRISMA. Foram analisados um total de 31 documentos publicados no período 2011-2021 sobre CLIL em informática e TIC em ambiente CLIL. Este artigo discute, primeiro, as vantagens do uso de CLIL na computação e, em seguida, ilustra os benefícios e desafios da aplicação das TIC nas aulas de CLIL. Finalmente, serão apresentadas as tendências da pesquisa CLIL aprimorada pela tecnologia, destacando as descobertas existentes e identificando as lacunas de pesquisa no campo. Finalmente, serão apresentadas as tendências da pesquisa CLIL aprimorada pela tecnologia, destacando as descobertas existentes e identificando as lacunas de pesquisa no campo. As deficiências e dificuldades mais importantes descritas na literatura relacionada são a pesquisa limitada sobre CLIL e CLIL apoiado em TIC em informática, a terminologia inconsistente para o uso de TIC em CLIL e a necessidade de cursos de formação CLIL apoiados em TIC para o uso eficaz das tecnologias digitais. Portanto, os resultados deste artigo identificam uma variedade de planos de pesquisa futuros para aumentar o CLIL eficaz e apoiado por TIC no campo da informática.

Palavras-chave (Fonte: Thesaurus de la Unesco): Aprendizaje integrado de contenidos y lenguas (AICLE); informática; Tecnologías de la Información y la Comunicación (TIC); tecnología; educación bilingüe; AICLE mejorado con tecnología; enfoque interdisciplinario; revisión sistemática.

Technology has influenced virtually every aspect of life today, and education is no exception. To succeed professionally in the information age, today's students need not only theoretical knowledge, but also other skills and literacies. The vital tools that help to facilitate 21st Century skills are information and communication technology (Stehle & Peters-Burton, 2019), computer science education (Nouri et al., 2019; Abesadze & Nozadze, 2020), and content and language integrated learning (Vukadin & Marković, 2019); therefore, teaching computer science in a CLIL environment utilizing a variety of digital technologies might result in a very productive synergy.

From the very beginning of CLIL, the choice of subjects has led to a lot of discussion (Wolff, 2007). While CLIL can be used for a wide range of disciplines, science, geography, history, and social sciences are most commonly taught through target languages (Pérez-Cañado, 2012). Nowadays, it is expedient to teach computer science through CLIL along with other subjects. This subject is known by various names in different European countries and languages (Tikhonenko & Pereira, 2018). "Computer Science," "Informatics," or "Informatics Education," "ICT," and "programming" are the terms used to describe the subject (Diethelm, 2013). Weise (2013) advocates computer science "as one of the subjects best suited for bilingual education." As stated by Marsh (2012), there are more opportunities for learners to learn and master a foreign language than ever before because "ICT, mass-media and Internet usage have expanded dramatically" (p. 245) over the past decades. Alginahi et al. (2009) remark that "Information Technology benefits are best reaped through the knowledge of the English language" (p. 112). Knowledge in the field of IT and computer literacy is mainly acquired through English.

However, there is a lack of knowledge in studies dealing with CLIL in the subject of computer science (Weise, 2013). Weise (2013) wondered why there is "so little tangible interest in bilingual Informatics classes" (p. 129). In his report, Weise (2013) outlined the key reasons why Informatics should be taught in English. To begin with, the language of Informatics is English, and English-language publications are

often more accessible than in other languages. Second, high-quality translation of academic content takes time. Therefore, if students want access to up-to-date information in this field, they need to have adequate English language skills. Moreover, students quite often need to understand the technical specifications if they want to learn successfully. In addition, there is a strong relationship between the functions of keywords in a programming language and the meaning of those words in English. It helps to understand the meanings of Informatics terms. Furthermore, bilingual education prepares students for work in these fields after graduation, as applicants and professionals are required to have specialized foreign language skills, usually in English.

Although the increase in effectiveness through the combination of teaching the Computer Science and English subjects has been pointed out several times, there are not many studies focusing on this topic — either referring to using English or to any other languages.

The present study aims to provide a review of the existing research on the role of CLIL in the subject of computer science, paying special attention to the use of digital tools in CLIL. The following were the research questions that drove and structured the analysis process:

- RQ1. How is CLIL realized in teaching computer science in English?
- RQ2. What is the role of ICT in CLIL classrooms?

Method

This systematic review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The PRISMA protocol developed by Liberati et al. (2009) includes checklist items that should be considered to increase transparency and accuracy of the review process. Items 12–16 and 19–23, which dealt with risk of bias and pooling of results from meta-analyses, were omitted as they pertained to meta-analyses and were not within the scope of this study (Pahlevan-Sharif et al., 2019).

Based on the objectives of the review, a protocol was prepared to guide the literature search. It contains information on search terms, databases, and selection criteria. Four databases were utilized to

conduct our search: Google Scholar (GS), Web of Science (WOS), Science Direct (SD), and ERIC. The search was conducted using two sets of terms according to two research questions:

Cluster 1: (CLIL OR “Content and Language Integrated Learning”) AND (“computer science” OR “Informatics” OR “programming”)

Cluster 2: (CLIL OR “Content and Language Integrated Learning”) AND (ICT OR “Information and communication technologies” OR “digital technologies”) OR “e-CLIL” OR “eCLIL” OR “Computer Assisted CLIL” OR “CA-CLIL” OR “Technology-enhanced CLIL” OR “TECLIL” OR “T-CLIL”.

Since SD requires no more than eight Boolean connectors per field, the second cluster for it was reduced as follows: (CLIL OR “Content and Language Integrated Learning”) AND (ICT OR “Information and communication technologies” OR “digital technologies”) OR “e-CLIL” OR “Computer Assisted CLIL” OR “CA-CLIL” OR “Technology-enhanced CLIL”.

The inclusion and exclusion criteria were developed in accordance with the recommendations of the PRISMA statement and based on the research objectives and questions (Table 1).

Table 1. Inclusion and exclusion criteria

| Characteristics of the literature | Inclusion Criteria | Exclusion Criteria |
|-----------------------------------|---|---|
| Type of publication | Journal articles, conference papers | Reports, books, book chapters, theses, dissertations |
| Time period | Only articles published in the last ten years (2011–2021) | Journal articles published before 2011 |
| Language | Articles are written in English and the course's language of instruction is English | Articles are not written in English and the course's language of instruction is not English |
| Geography | No exclusions | No exclusions |
| Population groups | Secondary and tertiary education students | Primary education students |

| Characteristics of the literature | Inclusion Criteria | Exclusion Criteria |
|--|---|--|
| Type of policies/ interventions in scope | Cluster 1: Studies on the use of the CLIL approach (dual focus on content and language) in computer science classes. Cluster 2: Studies on the use of ICT in CLIL classrooms | Cluster 1: Approaches of teaching subjects in English focused on content learning only (e.g., English Medium Instruction); language-oriented versions of CLIL Cluster 2: Subject-specific ICT tools (e.g., software for geography, music, etc.) |

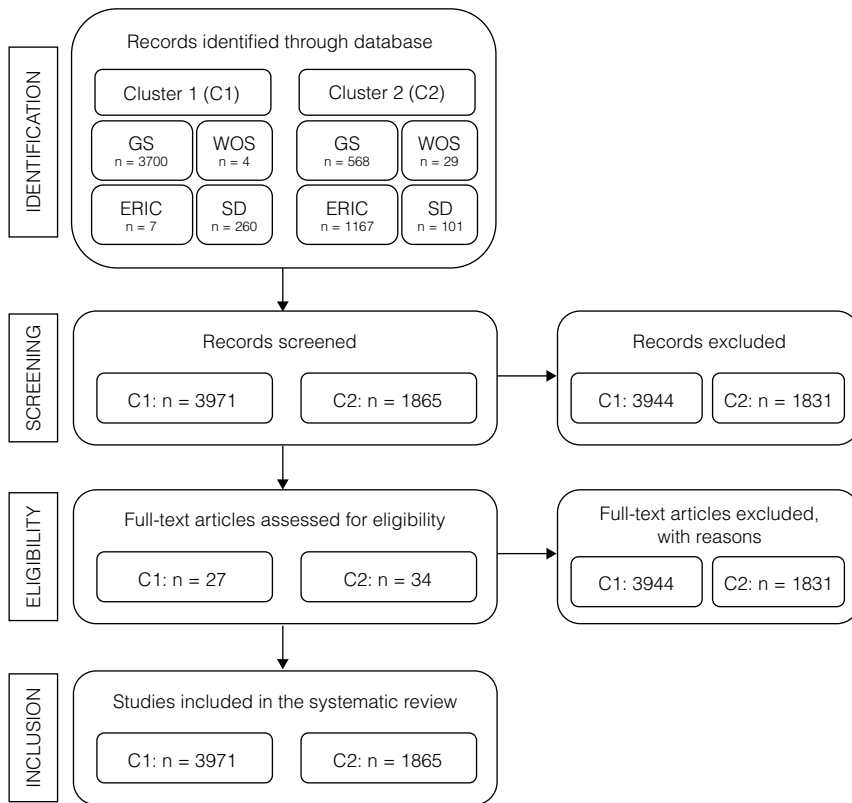
Source: Own elaboration.

Data collection was carried out according to the PRISMA protocol, in which the screening process was divided into four established stages (Figure 1). In the identification phase, a search in four databases using “Cluster 1” returned 3971 records, while “Cluster 2” yielded 1865 records. In the following screening phase, the number of publications was reduced to 27 records in the first cluster and 34 records in the second cluster by removing duplicate citations and applying inclusion and exclusion criteria. Following that, in the eligibility phase, the articles’ full texts were examined for the key information outlined in the research questions. Inclusion and exclusion criteria were applied exhaustively at this stage. Finally, at the inclusion stage, 5 articles in “Cluster 1” (RQ1) and 26 articles in “Cluster 2” (RQ2) were collected that made up the study sample.

Results

A total of 31 articles met the objectives of the study and the inclusion and exclusion criteria. An overview of the included articles presented in Table 2.

Figure 1. Study selection process



Source: Own elaboration.

Table 2. Overview of included articles

| Author (Year) | Level | Country | ICT tools | Role of technology in CLIL |
|--|-----------|---------|---------------------------------------|----------------------------|
| Cluster 1. CLIL in computer science | | | | |
| Batrova et al. (2017) | Secondary | Russia | MS Office, etc. | 1 |
| Griffith (2017) | Tertiary | Spain | Visualization tools | 1 |
| Hrytsiuk (2020) | Tertiary | Ukraine | Developed bilingual multimedia course | 1 |
| Paliwoda-Pękosz and Stal (2015) | Tertiary | Poland | Virtual learning environment (Moodle) | 2 |

| Author (Year) | Level | Country | ICT tools | Role of technology in CLIL |
|--|---------------------------|----------|---|----------------------------|
| Weise (2013) | Secondary | Germany | Representation forms of information (object diagrams, robots, etc.) | 1 |
| Cluster 2. ICT in CLIL | | | | |
| Abaunza et al. (2020) | Secondary | Spain | Duolingo and b-Learning | 1 |
| Abbate (2019) | Secondary | Italy | Corpora | 1, 3 |
| Adipat (2021) | Tertiary | Thailand | Videoconferencing, assessment tools, etc. | 1, 3 |
| Albero-Posac (2019) | Secondary | Spain | Clilstore, Moodle | 2 |
| Ángel (2015) | Tertiary | Spain | WebQuest | 1 |
| Cinganotto and Cuccurullu (2015) | Secondary | Italy | Video | 1 |
| Cinganotto (2017) | Secondary | Italy | Specific websites devoted to the project, digital content, blogs, rubrics, e-cards, online tests etc. | 1, 2, 3 |
| Cinganotto and Cuccurullo (2016) | Secondary | Italy | OER, Web 2.0 | 3 |
| De Waard and Demeulenaere (2017) | Secondary | Belgia | MOOCs | 1 |
| Fernández Fontecha (2014) | Tertiary | Spain | CLILQuest | 1 |
| García-Esteban et al. (2019) | Tertiary | Spain | Telecollaboration tools | 3 |
| Hernandez-Nanclares and Jimenez-Munoz (2016) | Tertiary | Spain | Online pre- and post-lecture assignments, social networks and blogging | 2, 3 |
| Krajka et al. (2016) | Secondary | Poland | Online interactive multimedia | 1 |
| Leto (2017) | Primary and low secondary | Italy | Edmodo, Mind map, Hotpotatoes, Kahoot, Power Point, Movie Maker, etc. | 1, 2, 3 |

| Author (Year) | Level | Country | ICT tools | Role of technology in CLIL |
|----------------------------------|------------|--------------------------------|---|----------------------------|
| Marengo-Domínguez (2017) | Secondary | Colombia | Blackboard Collaborate web-conferencing | 3 |
| Merino Villar (2011) | Secondary | Spain | Wiki | 3 |
| Navarro-Pablo et al. (2019) | Secondary | Spain | Made a tentative classification of digital resources and materials commonly used in CLIL | 1, 2, 3 |
| Ó Dónaill and Gimeno-Sanz (2013) | Secondary | Ireland, Spain | Clilstore | 1 |
| O'Dowd (2018) | Secondary | Spain | Virtual exchange or telecollaboration tools | 3 |
| Puspitasari (2020) | Tertiary | Indonesia | Mind mapping tools | 1 |
| Schietroma (2019) | Secondary | Italy | Digital materials about STEM content, portfolios, e-glossary, webpages, etc. | 1, 3 |
| Veselá (2012) | Secondary | Slovakia | Moodle | 2 |
| Wojtowicz et al. (2011) | All levels | 32 (mostly European) countries | ICTs (educational websites, smart boards, video conferences, etc.) and games-based learning | 1, 3 |
| Zaripova et al. (2019) | Tertiary | Russia | Web-based platforms for constructing websites | 1, 3 |
| Zhao et al. (2021) | Tertiary | China | Knowledge forum | 3 |
| Zhyrun (2016) | Tertiary | Colombia | Audio-visual materials | 1 |

Note. 1 – a provider of content and instructional tool; 2 – a learning management tool; 3 – a communication and collaboration tool.

Source: Own elaboration.

Existing findings about CLIL in computer science

In the articles related to the implementation of the CLIL approach in the subject of computer science, each author intended to answer the question of how to effectively teach computer science using CLIL. For instance, Hrytsiuk (2020) proposes to apply a competence-activity approach and make the learning content more communicative in nature. The author developed a bilingual multimedia course “Computer for Beginners” with a built-in dictionary of English terms, which consolidates the necessary knowledge and competencies in the subject, expands the skills of competent use of ICT tools and communication in English.

Weise (2013) demonstrates a methodological model of teaching computer science through CLIL. In this model, he describes five steps of introducing new content in the class: physical (e.g., representing a concrete object such as a moving robot, an experiment, or actions), figurative (e.g., a pictogram, an image, a schematic drawing), verbal (e.g., describing a process or situation), symbolic (e.g., object diagrams, graphs), and technical or mathematical (formula-based) form of representation (e.g., source code, pseudo-code, etc.). Based on this model, he presents two pieces of practical, approved teaching material that can be useful for Informatics teachers.

Batrova et al. (2017) describes the process of designing the content of the bilingual elective course “Information and communication technologies”. The curriculum was developed using the textbooks “Basic English for Computing” (Glendinning & McEwan, 2003) and “Oxford English for Information Technology” (Glendinning & McEwan, 2002) as guides. Students’ skills in solving practical problems were honed through labs, with the purpose of improving their skills of using different sources of data, transforming information, and presenting it in various forms, as well as independent works, such as critical reading of recommended literature, solving proposed problems with subsequent examination of solutions, and analysis of their activities. The students’ knowledge and skills were examined after each module was completed. According to the author, the use of the CLIL approach in the classroom contributed to the improvement of

students' English language skills without loss of quality of content knowledge.

An action research by Griffith (2017) investigated the challenges that eight Computer Science professors faced when they began teaching their subjects in English and looked for realistic solutions. Difficulties such as preparation of material, concerns about assessment, and individual concerns about foreign language performance for both students and instructors were identified. During the participatory research, the instructors were provided with trainings where the solutions to the challenges were suggested. For instance, it was noticed that professors who were uncomfortable with the requisite language tended to use a lot more text in their presentations of materials. The solution was to shorten and highlight the text and include an image that provides instant clarification. An interesting finding from this study was that the teachers with the strongest English skills were not necessarily the best content teachers. This means that CLIL is far more concerned with proper teaching than with proper foreign language use.

Paliwoda-Pękosz and Stal (2015) conducted a design research, the purpose of which was to investigate the possibility of using a Virtual Learning Environment (VLE) to support CLIL in computer science courses. The researchers proposed a framework for creating university courses based on the authors' experience and analysis of a survey of students at a Polish university. The authors identified benefits of VLE courses, such as publishing lecture materials in both languages, providing seminar materials (instead of printed handouts), conducting e-workshops, managing students' assignments, and facilitating communication.

It is worth noting that the aforementioned studies are the only ones that deal with CLIL in computer science, which illustrates a lack of knowledge in this area.

ICT in supporting CLIL

Advantages of ICT in CLIL

In comparison to CLIL in computer science, the area of ICT's impact on content and language integrated learning has been extensively studied, and these studies show that the use of ICT in CLIL teaching brings numerous benefits.

To begin with, students become more motivated in foreign language learning when ICTs are integrated into CLIL (Abaunza et al., 2020; De Waard & Demeulenaere, 2017; López-Pérez & Malagón, 2017; O'Dowd, 2018; Schietroma, 2019; Veselá, 2012), since motivation is a common feature of both CLIL and ICT, their combination can give students a synergic motivation to learn a foreign language (Veselá, 2012). The use of digital tools in CLIL classrooms allows teachers to organize various activities that motivate students and develop their linguistic skills (Schietroma, 2019), as well as give them the opportunity to be active participants and developers of their own educational process, instead of being passive recipients of information (Schietroma, 2019). Abaunza et al. (2020) observed in their research that the CLIL approach, together with ICT tools such as Duolingo, provokes the motivation of students who previously showed "a low attitude, low academic performance and a tendency to demotivate the apprehension and acquisition of English as a foreign language" (p. 102).

Hernandez-Nanclares and Jimenez-Munoz (2016) discovered that the use of CLIL in combination with online pre- and post-lecture assignments, social media and blogging as tools for further practice and integrating them into classroom practice improved students' achievement. They even concluded that, without ICT interventions, the long-term success of bilingual programs and their advantages are severely undermined compared to groups taught exclusively in the mother tongue. ICTs promote interaction between students and develop basic skills: working with new technologies, learning to learn, independent and autonomous learning, etc. (López-Pérez & Malagón, 2017). Learning can be customized to suit the individual needs of each student and materials can be accessed anytime and anywhere, allowing students to learn at their own pace (Albero-Posac, 2019).

Trends in research of ICT in CLIL

Nunan (2010) defined three major roles of technology in second-language classrooms: technology as a content carrier and instructional tool, as a learning management tool, and as a communication tool. These roles of ICT can also be applied to the CLIL classroom. The research trends on the application of ICT in CLIL were divided according to these roles.

Technology as a provider of content and instructional tool in CLIL

According to Nunan (2010), the computer acts as a carrier of content when it provides learners with reading and listening input. One of the ways that ICT can be beneficial in the context of CLIL is by adding hypertext and hypermedia, as they allow students to access information about specific concepts or ideas in various forms as written texts, images, videos, simply by clicking on the word they want to study further about. A good example of a CLIL website that uses hyperlinks is Clilstore (Albero-Posac, 2019), which was created as a result of the Tools for CLIL Teachers project funded by the European Union, where teachers can develop and share learning materials (Ó Dónaill & Gimeno-Sanz, 2013).

The article by Navarro-Pablo et al. (2019) presents the findings of a study conducted in eight Spanish schools on the views of CLIL teachers and learners on the integration of digital resources and materials in the classroom, especially how often and what digital resources have been used inside and outside of the CLIL classroom and what effect this had on students in L2 teaching-learning processes. The authors made a rough classification of ICT tools and resources commonly used in CLIL classes: hardware and software, files (e.g., films, music, eBooks), 1.0 and 2.0 content websites, social media, communication services, and online learning environments. The study indicates that those tools that promote collaborative studying, interpersonal communication, and learning autonomy are in the lowest priority among the digital resources that teachers use in their CLIL classes. Moreover, teachers do not fully use all the functions of ICT tools; for example, some of them use interactive whiteboards only as projectors.

Cinganotto and Cuccurullu (2015) investigated the role of another form of providing information, video, in a CLIL setting. This research indicates that videos play a critical role in a CLIL environment as they can be used at different stages of the lesson, such as brainstorming, introduction, practice and assessment, with the aim of engaging and motivating learners in a learner-centered perspective. Zhyrun (2016) discussed the benefits and limitations of developing audio-video materials adapted for university-level CLIL courses, comparing them with existing materials, and concluded that specially created videos were easier to understand and evoke positive emotions as they relate to students' life. Concept maps or mind maps help students to better comprehend the texts they read English (Puspitasari, 2020), encourage them to be more creative, and stimulate cognitive thinking skills.

Probably one of the widely used web-based activities in today's classroom is WebQuests. The effectiveness of a teaching approach where WebQuests, CLIL and STSE (Science, Technology, Society and Environment) were integrated was evaluated by Ángel (2015). The author points out WebQuest as a very attractive method, which provides guidance and structure for both students and teachers and stimulates higher-order thinking skills, describing it as "an inquiry-oriented lesson format in which most or all the information that learners work with comes from the web" (Ángel, 2015, p.1). Fernández-Fontecha (2014) described the CLILQuest as a type of WebQuest for the CLIL framework. The difference of the CLILQuest from the traditional WebQuest is that "the ICT-mediated tasks in a CLILQuest present characteristics that reinforce the dual teaching of content and language by engaging learners in active processing of information and construction of meaningful knowledge" (Fernández-Fontecha, 2014, p. 157).

The use of one of the relatively recent online learning phenomenon, Massive Open Online Courses (MOOCs), in CLIL classes was investigated by De Waard and Demeulenaere (2017). They carried out a year-long exploratory study that examined the outcomes of the MOOC-CLIL (Massive Open Online Courses and Content and Language Integrated Learning) project. According to the results of the surveys and the interviews, most of the participating students were intrinsically motivated, students became more aware of their own learning abilities, and their use of a foreign language increased. In addition,

many students improved their critical thinking and self-regulatory learning skills.

Krajka et al. (2016) discussed how CLIL integrated e-learning can be used to cultivate students' diverse competences for lifelong learning, as well as how teachers and students use and relate to digital CLIL materials, designed in an innovative multimedia supported learning project (E-Academy of the Future). A total of 160 school principals, 1017 teachers, and 13500 students were interviewed. The assessment revealed that students enjoyed using the e-learning materials and considered the content and language integration approach to be beneficial. Approximately 85.3% of the teachers asserted that, among all project-related materials, the e-learning units proved to be the most useful for forming core competences.

From the research conducted by Wojtowicz et al. (2011) among 238 CLIL educators and practitioners in over 30 (mostly European) countries, it appeared that ICT and games-based learning, in particular, are already extensively used in this area. In this study, the researchers sought to answer the question of how CLIL and ICT combined can improve the effectiveness of learning in both language and non-language subjects. Most respondents (71%) agreed that CLIL teaching with ICT support is more effective than traditional methods. It is worth noting that the authors used the term "e-CLIL" to describe the use of ICT in CLIL classes.

In Italy, the Ministry of Education launched a whole project called eCLIL, which pursued the goal of guiding and supporting schools in the preparation and implementation of CLIL modules with the use of ICT technologies. During this project, teachers were trained to apply CLIL and ICT in their lessons, and high-quality resources for students were developed, including project-specific websites, e-books, online assessments, blogs, and more (Cinganotto, 2017).

In her paper, Leto (2017) described the results of one of those projects conducted in Italy in 2015-2016 academic year, which involved 240 and 300 pupils from primary and low secondary schools, respectively, as well as approximately 60 teachers of different subjects. The results showed that the CLIL students acquired the same content as the students in the non-CLIL classes; however, their vocabulary was much larger, and they were able to use English to express what they

had learned. Moreover, students were more motivated to engage with topics that they had previously found boring. Zaripova et al. (2019) described and assessed how CLIL and ICT improve Master students' motivation. The combination of CLIL and ICT has made it possible to use a constructivist approach, the core elements of which are the ability to explore, experiment, construct, discuss, and analyse.

Technology as a learning management tool in CLIL

Technology as a learning management tool has become increasingly important, especially with the proliferation of non-free software such as Blackboard and Moodle (Nunan, 2010). Albero-Posac (2019) offered a proposal for enriching CLIL subjects with ICT, in which different digital tools and platforms, selected based on certain pedagogical principles, were garnered in the Moodle learning management system (LMS). The platform was designed to help students in their extracurricular time (since class time is very limited) to review what they have learned in class while also providing additional support to those who may need it and offering students the opportunity to expand their knowledge by working on both a language and a content level.

The article by Veselá (2012) describes design-based research where teaching was supported by the educational tools of Moodle. Veselá (2012) proposed the blend of Computer Assisted Language Learning (CALL) and CLIL as a methodology suitable for teaching English for Specific Purposes (ESP) and called it CA-CLIL (Computer Assisted Content and Language Integrated Learning). The author explained the differences between e-CLIL and CA-CLIL as follows: While the term *e-CLIL* only takes the “e” from the term *e-learning* to refer to any form of using ICT in CLIL methodology, CA-CLIL is a developed methodology based on common principles, united by common goals and motivation effective in teaching ESP. The research results show that the students trained in the CA-CLIL methodology had significantly better outcomes than other students in the non-CA-CLIL group in terms of their English proficiency and knowledge of the subject. Based on the analysis of the CA-CLIL lessons, the author emphasized that just teaching subjects in other languages and using computers in class cannot be considered as a CA-CLIL methodology. If the teaching does

not have the predominant features of CA-CLIL (flexibility, authenticity, task-oriented, student-cantered, and collaborative); if the role of the teacher is simplified to “lecturer”; if the technology is not used to improve all three phases of mastering a foreign language (input, perception-understanding-reception-integration and output); and if both subject and language goals are not pursued, then the lesson cannot be called a CA-CLIL lesson, and its success can be doubtful.

Technology as a communication and collaboration tool in CLIL

In the context of CLIL, online communication technologies have tremendous potential to help students to develop foreign language skills, intercultural competence, and better understanding of subject matter (O'Dowd, 2018). O'Dowd (2018) explored one of the effective ways to engage CLIL students in communication and collaboration — namely, Virtual Exchange. Virtual Exchange or telecollaboration is a practice in which students are involved in collaboration and online task-based interaction with partner students in other locations under the supervision of their teachers. This valuable tool can assist to achieve many of CLIL classroom learning objectives. For example, it allows students to practice their speaking skills in the target language with students from other countries on the topic of their subject area. Moreover, by communicating with people with different cultural background, students' intercultural competence will develop, and, finally, through meaningful, learner-centered activities, students are involved in learning by doing (O'Dowd, 2018). Likewise, the quantitative and qualitative findings of the research by Garcia-Esteban et al. (2019) show that using telecollaboration improved the learning to learn competence of teacher trainees in a CLIL environment.

Marenco-Domínguez (2017) studied the impact of peer tutoring and computer-based conferencing on students' fluency and concluded that student-student interaction improves not only speaking skills but also their motivation and self-confidence.

Wikis also provide a perfect environment for collaborative work in a CLIL context, where users work together to create and edit content on a website. Merino-Villar (2011) advocates using wikis in a CLIL class as a tool to help students improve their writing abilities in the foreign

language while also practicing and broadening their understanding of non-linguistic curricular subjects. Wikis allow teachers to track individual and group progress of students, which can help in determining each student's degree of contribution. In addition, while working on a wiki, students must critically read what others have written, which promotes a higher level of interactivity. The study by Zhao et al. (2021) examined the content knowledge and language outcomes of bilingual students who were exposed to two different learning environments — a Technology-Enhanced CLIL (TECLIL) project-based learning environment using Knowledge Forum (KF) and a CLIL project-based learning environment. The KF educational software was applied to facilitate collaborative exploration of subject concepts, organize project work and increase linguistic and literacy development. "Students explore a topic on KF by creating, reading, commenting on, and writing build-on notes in a collectively-created space" (Zhao et al., 2021, p. 3). The results show that the TECLIL classes outperformed the comparison classes both in terms of studying subject concepts and in the use of specific English.

An article by Cinganotto and Cuccurullo (2016) describes the possibilities of Open Educational Resources (OER) and digital tools in CLIL teaching. According to the authors, OER and ICT tools have significantly changed the educational landscape by allowing CLIL educators to communicate virtually and exchange ideas, best practices and materials, which helps them to improve the quality of learning, as the idea of OER is that the knowledge is publicly available, and anyone can share, use, adapt and re-share it. This is especially useful for CLIL teachers as they struggle to find specific materials and resources for content and language learning.

With a greater emphasis on improving communication skills in language learning these days, CLIL classes are an excellent place to incorporate ICT, as these communication tasks and situations can be easily completed and replicated using digital media (Navarro-Pablo et al., 2019).

The systematic review of the related literature on this field shows that there is a wealth of research on CLIL and the use of ICT in CLIL lessons. The most researched topics relate to the function of technology as a content supplier and instructional tool, as well as collaboration and communication tool in CLIL. Table 2 reveals that most of the articles come from Spain, with Italy in second place. Among the included articles, research at the secondary education level was more frequent than at the tertiary level. The articles often described communication and collaboration tools such as videoconferencing, telecollaboration, WebQuests and free digital programs that can be used to create and share student projects and products.

However, there are comparatively few research-based theories, and the available literature is rather limited. Therefore, there is a research gap concerning the usage of CLIL supported by ICT in teaching computer science. In addition, there is a tremendous interest in CLIL issues from language teachers and researchers, which is understandable given that CLIL is ostensibly a language pedagogy issue, while subject matter teachers' perspectives are uncommon (Veselá, 2012).

Another problem is the inconsistent terminology for using ICT in CLIL: in various literature, the combination of CLIL and ICT is expressed in different terms such as “e-CLIL” (Abbate, 2019; Wojtowicz et al., 2011) or “eCLIL” (Leto, 2017; Cinganotto, 2017) — both referring to the European Union funded project to develop and build digital resources for the use of CLIL — and “CA-CLIL” (Veselá, 2012), that is, computer-assisted CLIL. Moreover, in some literature, this blend is denoted as “TECLIL” (Zhao et al., 2021) or “T-CLIL” (Adipat, 2021) or technology-enhanced CLIL.

Several authors claimed that there is a shortage of sufficient materials dedicated to teaching computer science in CLIL (Griffith, 2017; Wojtowicz et al., 2011). Furthermore, there is a lack of understanding about CLIL methodology and ICT usage among teachers as they use them inappropriately, not taking into account the dual focus of CLIL, using digital technologies without correct methodology —some of them appear to be difficult to use, or they cannot take full advantage of all

their features (Griffith, 2017; Navarro-Pablo, 2019; Veselá, 2012). Therefore, there is a need for CLIL teacher training courses where teachers can learn how to use CLIL methodology and digital technologies effectively in their classes, as well as online communication places for exchanging ideas and experiences (Hrytsiuk, 2020; Wojtowicz et al., 2011).

Conclusion

The analysis of thirty-one papers provides an insight into the current state of the use of CLIL in computer science and the application of digital technologies in CLIL classrooms. The findings demonstrate that using technology-enhanced CLIL in computer science can assist learners in becoming more motivated, building language and content skills in the field of ICT, and developing lifelong learning skills. In order to more effectively teach computer science in the CLIL environment, the researchers recommend paying attention to the visualization of the input, using variety forms of presentation of the new material, working with specialized vocabulary, using ICT tools that require interactivity and collaboration and help to develop higher-order thinking, creativity and lifelong learning skills, as well as applying a competence developmental approach. It is also suggested to use a digital course of the subject with various activities that allow students to practice at their own pace and access from any location.

Among the limitations of the study is the fact of the exclusion of articles that are not written in English. It should be recognized that there may be many papers reporting teaching methods in other languages that have likely not been reviewed. Inclusion of only journal articles and conference proceedings is also another limitation, as this may result in the omission of valuable data that may be present in edited editions.

Progress has been made in the research of ICT-supported CLIL, but many important research questions remain — especially regarding the subject of computer science. The above-collected findings of the literature review can be used as recommendations for future research directions and thereby for filling the detected research gaps.

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