Avaliação das práticas de fomento da Economia Circular em Manaus – AM: Estudo de múltiplos casos em uma escola pública e em duas empresas do polo industrial

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RESUMO

A proposta deste trabalho incidiu em investigar as práticas de gestão, com base nas premissas da economia circular, em uma escola pública da cidade de Manaus, em uma empresa que atua no polo industrial da região e em uma microempresa que atua no ramo de produção de utensílios de madeira. Com respeito à escola pública, a proposta consistiu na avaliação da percepção dos alunos sobre os conceitos relacionados à educação e sustentabilidade, e como a economia circular pode ser impulsionada na sociedade por meio de políticas educacionais consistentes. Com base na aplicação de um questionário aos alunos, foi possível avaliar sua percepção sobre o tema ambiental e a promoção de ações circulares. Como conclusão do estudo na escola, a existência de uma política educacional sólida é capaz de impulsionar os conceitos preconizados pela economia circular, criando um círculo virtuoso natural para que esses conceitos estejam fortemente enraizados em todas as camadas da formação educacional do indivíduo. Já a marcenaria sustentável explora o conceito de economia circular com base no uso de resíduos de madeira provenientes do processo produtivo de uma empresa que atua no setor de produtos de higiene e limpeza do Polo Industrial de Manaus, que alimentam o processo de fabricação de uma Oficina Sustentável que fabrica produtos personalizados. A metodologia deste trabalho consistiu em explorar as etapas de seu processo de fabricação e revelou o potencial a ser explorado na região devido às oportunidades econômicas e aos impactos socioambientais. Por fim, o último estudo deste trabalho incidiu na avaliação do desenvolvimento de um produto a partir de sobras do processo produtivo de uma empresa fabricante de lápis de cor. O planejamento de um produto com os atuais princípios de economia circular aumentou a criatividade e a inovação para criar novos métodos que podem ser aplicados desde a fase de planejamento até o produto final chegar ao mercado.

ABSTRACT

The purpose of this work was to investigate management practices, based on the premises of the circular economy, in a public school in the city of Manaus, in a company that operates in the industrial pole of the region and in a micro company that operates in the branch of production of wooden utensils. With respect to the public school, the proposal consisted of evaluating the students' perception of the concepts related to education and sustainability, and how the circular economy can be boosted in society through consistent educational policies. Based on the application of a questionnaire to students, it was possible to assess their perception of the environmental theme and the promotion of circular actions. As a conclusion of the study at school, the existence of a solid educational policy is capable of boosting the concepts advocated by the circular economy, creating a natural virtuous circle so that these concepts are strongly rooted in all layers of the individual's educational background. Sustainable joinery, on the other hand, explores the concept of circular economy based on the use of wood residues from the production process of a company that operates in the hygiene and cleaning products sector of the Manaus Industrial Pole, which feeds the manufacturing process of a Workshop Sustainable that manufactures customized products. The methodology of this work consisted of exploring the stages of its manufacturing process and revealed the potential to be explored in the region due to the economic opportunities and socio-environmental impacts. Finally, the last study of this work focused on evaluating the development of a product based on leftovers from the production process of a company that produces colored pencils. The planning of a product with the current principles of circular economy has increased creativity and innovation to create new methods that can be applied from the planning phase until the final product reaches the market.

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Para minha mãe, Maria Ester Albuquerque de Oliveira (*in memoriam*), por ter me preparado para os passos que pude dar.

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LISTA DE ABREVIATURAS

INTRODUÇÃO

Sabe-se que a sociedade, desde os primórdios, usufrui dos recursos ambientais para satisfazer as suas necessidades. A princípio, a utilização desses recursos era apenas em função da subsistência, posteriormente, transcendeu-se para a satisfação de meras necessidades e começou-se a visar o lucro.

Durante a Primeira Revolução Industrial, iniciada na Inglaterra no século XVIII, houve um marco no consumo de recursos naturais. Foram criadas maquinas à vapor para substituir modelo de produção de bens anterior. Essas máquinas funcionavam através da combustão do carvão mineral e foram aplicadas inicialmente na indústria têxtil e depois fora ampliada para outros segmentos.

Na segunda metade do século XIX, iniciou-se a Segunda Revolução Industrial que além de ter se expandido a outros países, trouxe novidades para a civilização como, por exemplo: a invenção da luz; a descoberta do petróleo e o motor a combustão. A partir dessa ascensão industrial, infere-se que:

- "[...] houve a redução dos recursos naturais e aumento da emissão de carbono, poluição e problemas de saúde. " (AHUTI, 2015);
- Houve a redução do espaço natural, aumento do consumo de energia e de lixo por habitante (NASCIMENTO, 2012);
- A cada ano, 6 milhões de hectares de terra produtiva se torna um deserto; chuvas ácidas matam florestas e danificam as arquiteturas herdadas das nações e a queima do combustível fóssil aumenta o aquecimento global (BRUNDTLAND, 1987).

Constata-se também que não somente as indústrias contribuíram significativamente para a degradação do meio ambiente, mas também o crescimento populacional que incentivou o aumento da demanda para abastecer as suas necessidades (AGNER; STADLER, 2004).

Em suma, pode-se perceber que o desenvolvimento da sociedade fora se tornando cada vez mais insustentável, gerando uma preocupação aos cientistas.

Somente a partir da década de 60, com a publicação do livro A Primavera Silenciosa e com o Clube de Roma, a preocupação com o meio ambiente tomou proporções maiores. Nesse início de movimentos ambientalistas, fora lançado por quatro cientistas o relatório The Limits to Growth.

De acordo com Meadows et al. (1972), o crescimento desenfreado da população irá levar ao esgotamento dos recursos em dentro de cem anos, entretanto, afirma que é possivel reverter essa situação se o cresimento diminuir, além de estabelecer uma condição de estabilidade ecológica e econômica que seja sustentável. Se a população mundial atentar-se aos problemas ambientais, aumentará as chances de sucesso.

Na década de 80, a conscientização ambiental globalizou-se com a publicação do relatório Nosso Futuro Comum, também conhecido por Relatório Brundtland. Em 1972, na United Nations Conference on the Human Environment, fora delineado os direitos humanos em três aspectos principais: direito a comida adequada, água potável e de decidir o tamanho de suas famílias (BRUNDTLAND, 1987).

Dada a importância de inserir o desenvolvimento sustentável na sociedade, surgira a ideia da economia circular (E.C) que "[...] busca a circularidade no uso de materiais e de energia de forma intencional no projeto do produto" (RIBEIRO; KRUGLIANSKAS, 2014). Nesse sentido, busca-se desenvolver ações voltadas para se discutir as práticas de consumo, a reintrodução na cadeia produtiva de materiais não servíveis ou não utilizados, cultura da reutilização, ações estas que transcendam o processo produtivo e que tenham alcance em nosso cotidiano.

Com o advento de novas tecnologias e uma demanda crescente de produtos, nosso modelo econômico linear torna-se insustentável e coloca em risco a sobrevivência das futuras gerações, tendo em vista que vivemos em um planeta com recursos finitos. Vieira (2014) questiona o modelo progressista de desenvolvimento que vem sendo disseminado em forma de um direito de todos, com base na exploração desmedida de recursos naturais, tendo como consequência a devastação do meio ambiente.

Conforme o relatório de Gerenciamento de Resíduos na América Latina e Caribe, elaborado pela Organização das Nações Unidas, a geração dos resíduos sólidos nessa região tende a aumentar consideravelmente, passando de 541.000tons/dia, resultando uma

média de 1Kg/dia por pessoa em 2014, estimando-se alcançar 670.000tons/dia até o ano de 2050, ou seja, um aumento de 25% na nossa geração de resíduos (ONU, 2018).

Tal previsão coloca a sociedade diante de uma situação séria, pois estamos deixando um passivo de degradação ambiental para as futuras gerações, comprometendo sobremaneira os recursos naturais necessários que mantém um ecossistema do planeta Terra e que garantem para uma vida plena e saudável.

Dados do Panorama dos Resíduos Sólidos no Brasil de 2010 e 2017, elaborado pela Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais - ABRELPE, confirmam esse crescimento na geração de resíduos, considerando que em 2009 foi gerado o equivalente a 57.011.136 toneladas ao ano e ao final do 2017 compilado o valor de 78.425.360 ton/ano (ABRELPE, 2010 e 2017), o que confirma as estimativas da ONU, aumentando nossa taxa em 27% nesse hiato de 10 anos.

Diante disto, faz-se necessário o uso responsável dos recursos naturais, mitigando sua extração e promovendo a utilização dos resíduos gerados, transformando-os em matéria-prima para novos produtos. Leitão (2015) defende a necessidade de uma nova abordagem das operações das empresas, pautada na racionalidade econômica, porém guiada pelo pilar ambiental como cerne das decisões.

A proposta se faz necessária, pois precisamos viabilizar um novo método para o gerenciamento de resíduos para iniciar nossa transição para uma economia circular, tema que vem vendo sendo discutido nos principais fóruns mundiais, atacando a problemática dos resíduos sólidos.

CAPÍTULO 1 – Enquadramento do Problema

Esta seção tem o objectivo de mostrar o problema de pesquisa adotado. Para tanto, primeiramente faz-se necessário entender a importância do tema, assim como justificar a sua investigação. Na sequência o problema propriamente é apresentado e, por último, o objectivo geral e os objectivos específicos da pesquisa são abordados.

1. 1. Problemática

O município de Manaus, capital do Amazonas, possui uma população de 1,793 milhões que gera em torno de 76 mil toneladas/mês de resíduos sólidos e 2.500 toneladas/dia, dos quais somente 0,005% são destinados a reciclagem retornam para uma cadeia produtiva novamente, gerando empregos e beneficiando a economia, o meio-ambiente e a saúde de todos os envolvidos.

Todo esse resíduo tem como destino o aterro sanitário da cidade, que está em funcionamento desde o ano de 1989, o qual atingirá sua capacidade limite em 2021, momento em que não mais poderá receber toda essa demanda. Vale salientar, ainda, que é dever do Poder Público defender e preservar o meio ambiente ecologicamente equilibrado para as presentes e futuras gerações, devendo, para tanto, promover a educação ambiental e a conscientização pública, em todos os níveis de ensino, a fim de assegurar a efetividade deste direito, isto é o que consta no texto da Constituição Federal de 1988, no art. 225, § 1º, VI.

Nesse mesmo sentido, a Política Nacional de Resíduos sólidos traz a educação ambiental como um de seus instrumentos (art. 8º, VIII, da Lei nº 12.305/2010), o qual pode viabilizar a mudança de um problema social estabelecido pelo próprio homem, incumbindo, também, ao Município, sua promoção, em consonância com o que dispõe a Carta Maior. Pode-se concluir, então, que não se possui um sistema integrado dentro das esferas pública e privada aptas a lidar com a problemática dos resíduos sólidos. Isso porque, fica evidente que a esfera pública não dispõe da formação necessária para atuar

com educação ambiental junto à sociedade, mais especificamente no ambiente escolar. Já no âmbito privado, as empresas convivem com o dilema da produção mais limpa, a busca pela sustentabilidade, bem como com a adequada destinação dos resíduos que geram em seus processos, de forma direta e indireta.

O aumento da população mundial e sua concentração em grandes cidades resulta na crescente demanda por produtos em larga escala, unido com a falta de uma visão holística por parte do poder público, acarreta a um momento de perdas econômicas e, também, está causando impactos ambientais negativos (ELLEN MACARTHUR FOUNDATION, 2015). A população precisa ser educada a partir de novos paradigmas, principalmente acerca da sua responsabilidade com o meio que o rondeia como as consequências do consumo e a necessidade de se minimizar a geração de resíduos.

Os padrões do sistema de economia linear de usar e jogar fora precisam ser quebrados e ser construindo os ideais da economia circular, replicando o funcionamento biológico da natureza e introduzindo essa ideia no campo industrial (ONU, 2019). Precisa-se começar a pensar nos resíduos como materiais primas secundárias, reinserindo-o no fluxo produtivo e, assim, evitando uma perca econômica e uma busca maior de recursos naturais, uma vez que o planeta não tem capacidade para sustentar os atuais hábitos de consumo.

O conceito principal da economia circular é eliminar o termo “resíduo”. O que antes era considerado resíduo deve agora ser encarado como matéria-prima pronta para ser remanufaturada, e isso deve ser mantido de forma contínua em um ciclo industrial (LEITÃO, 2015). A partir do momento em que um material que seria previamente descartado se tornar um recurso, há um novo campo econômico aberto e com bastante potencial de aproveitamento, pois cerca de 30 a 40% do que é destinado aos aterros são passíveis de reciclagem, isso sem considerar a porcentagem de resíduos orgânicos (IPEA, 2017). Uma das formas de instaurar o desenvolvimento sustentável é aplicando metodologias que causem o mínimo de danos ambientais e que consumam o mínimo de recursos naturais, principalmente os não-renováveis.

A proposta deste trabalho é aplicar o conceito da economia circular em ações de cunho ambiental em uma escola pública, bem como no desenvolvimento do projeto de produto a partir de resíduos gerados por uma empresa que atua no Polo Industrial de Manaus.

1. 2. Delimitação do Problema

O tema apresentado delimitou-se na análise das práticas de descarte de resíduos de uma escola pública e de duas empresas do polo industrial na cidade de Manaus, de grande e pequeno porte.

1. 3. Formulação do Problema

Conforme Silva (2016), os temas de coleta seletiva e descarte de resíduos estão classificados em último grau de prioridade de todos os temas que a escola trabalha dentro da perspectiva da Educação Ambiental, conforme a Tabela I.

Portanto conclui-se que os temas não são assuntos tratados com a devida importância, nem em termos teóricos, muito menos em atividades práticas que treinem o indivíduo para a ações mais ambientalmente solidarias a natureza e a preservação do ecossistema.

Tabela 1 - Grau de relevância dos itens da Educação Ambiental.

Temas prioritários	Alto (1 -3)	Médio (4-7)	Baixo (8-10)	Total
1º - Consumo de água	92	7	6	104
2º - Consumo de energia	65	30	9	104
3º - Higiene Pessoal	66	25	13	104
4º - Respeito ao patrimônio material	32	51	21	104
5º - Cuidado com plantas	8	80	16	104
6º - Cuidado com animais	11	69	24	104
7º - Reuso de objetos	2	44	58	104
8º - Coleta Seletiva	20	54	30	104
9º - Descarte de resíduos	6	33	55	104
10º - Consumo de produtos orgânicos	9	25	70	104

Fonte: SILVA, 2015.

A Figura I explora o modelo clássico da Economia Circular, onde poder público, sociedade civil e empresas privadas atuam em plena cooperação, atuando cada uma em um determinado momento do processo, em perfeita sinergia, fazendo cada um o seu papel na cadeia para o bom relacionamento do homem com o meio-ambiente.

Figura 1 - Fluxo de Fomento da Economia Circular.

Tendo em vista que as discussões referentes ao tema estão cada vez mais presentes nas agendas dos países comprometidos com o bem-estar global, essa pesquisa busca responder as seguintes perguntas:

- Como a educação ambiental pode se tornar a base para a criação de políticas públicas e fomentar a economia circular?
- Como o desenvolvimento sustentável de produtos podem apoiar as ações ambientais e fomentar a economia circular?.

1. 4. Objetivos da Pesquisa

1. 4.1. Objetivo Geral

Avaliar as ações de fomento da economia circular na cidade de Manaus no âmbito de uma escola púbica, empresa de grande porte e de pequeno porte.

1. 4.2. Objetivos Específicos

a) Aplicar questionário visando avaliar a percepção das práticas ambientais como resultado de ações educacionais;
b) Avaliar o ciclo de produção, processamento e descarte das empresas em estudo;
c) Propor um projeto de produto, onde no seu processo de desenvolvimento seja aplicada a economia circular.

CAPÍTULO 2 – Fundamentação Teórica

Esta seção de fundamentação teórica deste projeto de pós-doutoramento apresenta a sustentação teórica acerca dos e fundamentos da economia circular, sustentabilidade, educação ambiental e desenvolvimento de projetos.

2. 1. Fundamentos da Economia Circular

Segundo *Consumers International Org*. (2019), muitas indústrias vêm aplicando a obsolescência programada em seus produtos e isso significa que os produtores estão deliberadamente projetando produtos que falhem prematuramente ou que se tornem desatualizados para que os consumidores adquiram um novo produto ou uma atualização.

Algumas indústrias ainda inviabilizam a reparação de seus produtos, o que fortalece ainda mais o consumismo e, consequentemente, a contribuição com o desperdício de matéria prima e poluição. Em contrapartida a essa problemática, está o desenrolar da 4ª Revolução Industrial que "alavancou a tecnologia digital e avanços em novas tecnologias que incluem a Internet das Coisas, impressora 3D e robotização, criando novas oportunidades em como os recursos e produtos são usados e consumidos" (DE ANGELIS, 2018).

Ademais, surge a sistemática da Economia Circular que traz uma abordagem que incorpora as preocupações ambientais ao desenvolvimento econômico e, assim, promove uma maior proficuidade dos recursos, reduzindo os desperdícios e a poluição. A partir disso, depreende-se que "a mudança para a E.C. vai além do modelo de economia linear que consiste em extrair, processar, consumir e despejar" (GALLAUD e LAPERCHE, 2016) e também que, devido aos constantes avanços tecnológicos, é possível implementar o modelo E.C.

Em 2014, a *Commissariat général au développement durable* (Comissariado Geral para o Desenvolvimento Sustentável) publicou um estudo sobre as políticas públicas dedicadas à E.C. Quatro países foram selecionados para ser a fonte de dados e

um deles fora o Japão, que mostrou que a transição para essa sistemática é uma solução para a falta de recursos no país. Na China, a E.C. é uma prioridade nacional, pois é um ponto-chave para a grande dependência do país em relação a energia e a matéria prima bruta (GALLAUD e LAPERCHE, 2016). Weetman (2019) frisa que "a economia circular pode proteger as empresas contra a escassez de recursos e a volatilidade de preços, criando oportunidades para o desenvolvimento de métodos de produção e consumo inovadores e eficientes" além de economizar energia e prevenir danos irreversíveis que são causados pelo consumo de recursos, mostrando que é um importante plano de ação dentro da parte política e de negócios.

A E.C. ocorre quando o fluxo dos materiais envolvidos na produção de um produto segue os seguintes princípios de acordo com (ROMERO e ROSSI, 2017):

a) **Nutrientes biológicos**: são projetados para adentrar a biosfera de forma segura;

b) **Nutrientes técnicos**: são projetados para circular em alta qualidade nos sistemas produtivos, de forma que não adentre a biosfera e seja possível a sua regeneração e restauração.

É importante tratar os materiais dessa forma para que seja estendido o seu período de uso e encorajam o pensamento de tornar um produto regenerativo e avançado. (MCDONOUGH e BRAUNGART, 2002). Os princípios de *Cradle to cradle: remaking the way we make things*, obra criada pelos autores, pode ser resumido da seguinte forma:

1. **Saúde dos materiais**: valorizar os materiais como nutrientes para ciclos seguros e contínuos;
2. **Reutilização dos materiais**: manter fluxos ininterruptos de nutrientes biológicos e técnicos
3. **Energia renovável**: impulsionar o seu uso em todas os processos;
4. **Manejo da água**: tratar a água como um recurso valioso;
5. **Justiça social:** celebrar todos os sistemas sociais e naturais.

O escopo para aplicar esse conceito da E.C. está no Produto Circular que, segundo Ellen MacArthur Foundation (2015), é o resultado de um design que pode significamente reduzir a lista de materiais e as despesas com os desperdícios. Os autores (BOCKEN et al., 2016) afirmam que há diferentes estratégias que podem desacelerar o *loop* do consumo de recursos quando o produto é projetado para ter uma vida longa e também

quando é viabilizada a extensão de sua vida por meio de fácil reparo e Markeset e Kumar (2003) reforçam que se um produto é bem projetado e é de alta qualidade, as necessidades de realizar manutenções no sistema são reduzidas. Além disso, um produto deve possuir fácil atualização e adaptabilidade.

Ademais, outra estratégia do produto circular está na eliminação no *loop* de consumo dos recursos, onde deve-se viabilizar a desmontagem e a reinserção do produto na manufatura em prol de aumentar o ciclo de vida dos nutrientes técnicos envolvidos e recuperá-los quando atingirem o final do seu ciclo de vida (ROMERO e ROSSI, 2017).

Weetman (2019), cita os fundamentos que sustentam a visão de economia e sociedade sustentável e, consequentemente, os aplicáveis à economia circular são:

- **Conservação da natureza:** é por meio da natureza que os recursos a qual a sociedade depende são extraídos e a sua biocapacidade depende da população regional e do estilo de vida;
- **Limitação da toxicidade**: protegendo a saúde e segurança dos seres vivos de, por exemplo, metais pesados e pesticidas. Essa proteção exige exige medições exatas da quantidade desses materiais tóxicos e avaliação da capacidade da natureza em absorver e processas as toxinas;
- **Produtividade dos recursos**: isso ocorre com a redução de uso dos materiais por parte dos países industrializados, ou desmaterializando-se, para que outros países também possam se desenvolver, com o propósito de reduzir impactos adversos além de reduzir a desigualdade entre os países.

Seguindo a linha de raciocínio de Ellen MacArthur Foundation (2015) e Romero e Rossi (2017), a Economia Circular se fundamenta em três concepções:

1) Quando há a necessidade de recursos, o sistema circular seleciona tecnologias e processos que usufruem de recursos renováveis ou então segue o princípio da *industrial symbiosis* [Tradução: indústria da simbiose] que a *International Synergies Limited* (2019) explana que ao invés dos resíduos gerados por um processo serem destruídos ou despejados ao meio ambiente, podem ser utilizados como um input de um outro processo;
2) Projetar produtos para a remanufatura, renovação e a reciclagem de forma que o material ou recurso desperdiçado assumam uma nova forma de valor com o objetivo de aumentar a sua produtividade, eficiência e redução de desperdício.

Ademais, a vida útil dos produtos ser prolongada e todos os materiais (nutrientes) de um produto devem ser escolhidos com base na *recyclability nature* [Tradução: Natureza reciclável] e deve ser estimulada a reinserção segura de nutrientes biológicos na biosfera para decomposição;

3) Reduzir danos a qualquer elemento do meio ambiente.

Ellen MacArthur Foundation (2015) acrescenta também que há outras características que firmam a economia circular:

- **As perdas são excluídas desde o princípio**: os nutrientes técnicos sempre serão projetados para serem reaproveitados, renovados e atualizados; a geração de resíduos é intencionalmente excluída, pois há o pensamento sistêmico de que o resíduo de uma espécie é o alimento de outra e os nutrientes biológicos não são tóxicos;
- **A diversidade faz a força**: as economias precisam ter modelos de negócios diversificados para que haja equilibrio e sucesso a longo prazo que, utilizando a natureza como modelo que possui vários sistemas atuando em conjunto, empresas e países podem explorar a diversidade para promover resiliencia e recursos (WEETMAN, 2019);
- **Fontes de energia renováveis movem a economia**: a energia necessária para a E.C. deve ser renovável de modo a reduzir a dependência dos recursos naturais (principalmente os não renováveis como petróleo);
- **Pensamento sistêmico**: nos elementos do mundo, há diferentes sistemas complexos os quais vinculam-se uns aos outros como as empresas, pessoas e a flora;
- **Feedback devem refletir os custos reais**: na E.C., os preços funcionam como mensagens, portanto precisam refletir todos os custos, inclusive os de externalidades negativas.

A partir das abordagens exploradas previamente, Weetman (2019) propõe a seguinte estrutura da E. C. para um produto, conforme a Figura 2:

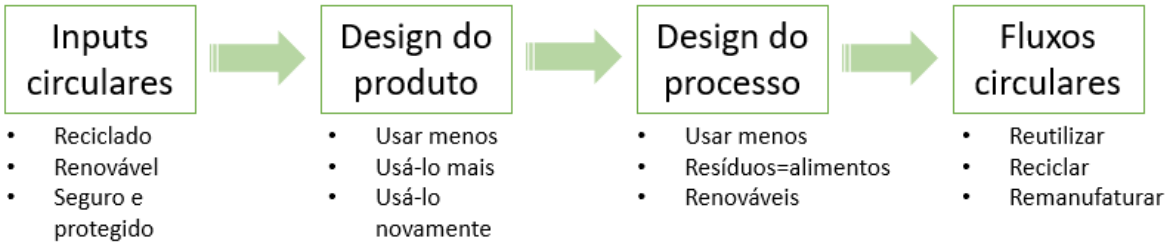

Figura 2 - Estrutura da Economia Circular com o foco no produto.
Fonte: Adaptado de Weetman (2019).

Uma estratégia de implementação da Economia Circular proposta por Ellen MacArthur Foundation (2015) é a Estrutura ReSOLVE, detalhada na Tabela2, que consiste em seis ações, as quais são: *regenerate, share, optimise, loop, virtualise and exchange* (regenerar, compartilhar, otimizar, ciclar, virtualizar e trocar).

Tabela 2 - Estrutura ReSOLVE.

REGENERAR/*REGENERATE*	• utilizar energia e material renovável; • recuperar, reter e restaurar a saúde dos ecossistemas; • devolver recursos biológicos recuperados a biosfera.
COMPARTILHAR/*SHARE*	• compartilhar ativos; • reutilizar/usar produtos de segunda mão; • prolongar a vida dos produtos por meio da manutenção, projetando visar a durabilidade e possibilidade de atualização.
OTIMIZAR/*OPTIMISE*	• aumento do desempenho/eficiência de um produto; • remover resíduos na produção e cadeia de suprimentos; • melhorar big data e automação.
CICLAR/*LOOP*	• remanufaturar produtos ou componentes; • reciclar materiais; • usar digestão anaeróbia; • extrair substancias bioquímicas dos resíduos orgânicos.
VIRTUALIZAR/*VIRTUALISE*	• desmaterializar diretamente e indiretamente.
TROCAR/*EXCHANGE*	• substituir os materiais não renováveis; • usar tecnologias avançadas e mais limpas como impressoras 3D; • optar por novos produtos.

Fonte: Adaptado de Ellen MacArthur Foundation (2015).

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2. 1.1. Economia Circular versus Economia Linear

Desde que o fenômeno da industrialização surgiu, nossos processos produtivos foram construídos de forma linear, onde se extrai a matéria-prima da natureza, dela se produz um bem, o mesmo após o uso/consumo vem a ser descartado, e após esse ciclo existe o descarte dos resíduos contidos tanto na produção desse bem de consumo, assim como após o seu uso o descarte, utilizando esse modelo se presume que a natureza é uma fonte inesgotável de recursos naturais. Conforme Foster et al. (2016), com o aumento de produção e consumo ocorre também o aumento sistemático da extração de recursos naturais e, consequentemente, dos resíduos gerados.

Manter o sistema linear de produção como padrão resulta em dois grandes problemas, na primeira ponta que nossos recursos naturais são finitos consequentemente o uso irresponsável dos mesmos comprometerá gerações futuras e na outra ponta temos a geração de resíduos sem procedentes, onde o homem não assume sua responsabilidade acerca dos resíduos que gera tanto na produção dos bens quanto no pós consumo e descarta esses itens de forma leviana na natureza para que a mesma se encarregue de prover soluções para lidar com esse resíduo.

Estamos inseridos em um cenário devastador e embarcados em uma corrida contra o tempo na busca de soluções, inovação de produtos e serviços, processos produtivos e modelos de negócios precisam ser repensados a partir do paradigma da sustentabilidade para gerem crescimento econômico ao passo que permita o bem-estar social e a longevidade dos nossos recursos naturais (Andrade et al., 2016).

Contrapondo o modelo linear de produção que se mostra insustentável, temos a economia circular, que funciona como ciclo fechado renunciando ao ciclo do “produzir, usar, descartar” e fazendo a transição para o ciclo de reuso e reciclagem, onde os recursos naturais são obtidos na natureza, porem ao invés de serem descartados e perderem valor econômico, são novamente inseridos em ciclos produtivos que vão sendo reusados e reciclados ao longo de sua cadeira de valor (Foster et al., 2016).

Conforme Ellen MCArthur (2017) a economia circular faz distinção entre dois ciclos, o ciclo biológico e o ciclo técnico, onde o ciclo biológico como alimentos e madeira por exemplo são orgânicos e, portanto, projetados para retornar ao sistema por processos de compostagem, onde os mesmos regeneram os sistemas vivos, como o solo por exemplo, que por sua vez reestrutura o ciclo dos recursos naturais novamente. Já os

ciclos técnicos se referem a materiais industrializados, que recuperam produtos, componentes e materiais através das estratégias de reuso, reparo, manufatura ou reciclagem.

Segundo Andrade et al. (2016), as empresas podem adotar a economia circular de acordo com três ordens, econômica, legislativa e ecológica. A ordem econômica diz respeito as operações indústrias por via de reciclagem provenientes de reuso e da manufatura. A ordem legislativa relaciona-se com o atendimento da legislação, vide a lei nº 12.305 que versa sobre a Política Nacional dos Resíduos Sólidos (PNRS). E as razões ecológicas se relaciona com a preservação do meio ambiente, onde as empresas precisam repensar seus processos e produtos dentro de uma perspectiva sustentável.

2. 1.2. Economia Circular e Sustentabilidade

A economia circular, já há algum tempo, tem sido bastante discutida como forma de revitalizar os processos econômicos e produtivos sob a ótica da redução de impactos ao meio ambiente e impulsionando a sustentabilidade.

Nesse sentido, a definição clássica de EC remete às contribuições de pesquisadores que atuam nesta área, e a definem como sendo a substituição de um modelo linear por um modelo circular, onde resíduos são insumos de um novo processo ou produto que se relacionam num loop fechado (ELLEN MACARTHUR FOUDATION, 2020; MacArthur, 2013; Weetman, 2017).

A transição do modelo linear para o modelo circular é apoiada por uma transição para fontes de energia renovável, de modo que o modelo circular constrói capital econômico, natural e social e está baseado nos seguintes princípios: eliminar resíduos e poluição desde o princípio, manter produtos e materiais em uso e regenerar sistemas naturais (“Ellen MacArthur Found.,” n.d.). Contudo há estudos que indicam que nem sempre a sistemática de usar resíduo para alimentar outro processo resulta em produtos com o mesmo nível de desempenho do que aqueles feitos com matéria prima original (Zink & Geyer, 2017), além do que as ideias da EC precisam de maior apoio científico (Korhonen, Honkasalo, & Seppälä, 2018) e serem medidas de forma adequada por meio de indicadores apropriados para se avaliar a efetividade das ações circulares (Busu & Trica, 2019; Moraga, Gustavo; Huysveld, Sophie; Mathieux & Blengini, Gian Andrea; Alaerts, Luc; Van Acker, Karel; de Meester, Steven; Dewulf, 2019).

Com efeito, as ações preconizadas pela EC nos levam, inevitavelmente, a avaliar como estas ações possuem forte relação com os conceitos de Sustentabilidade, uma vez que o termo está associado às ações e atividades humanas que visam suprir as necessidades atuais dos seres humanos, sem comprometer o futuro das próximas gerações ("Sustainable Development Goals," n.d.; Wehrden, Oheimb, Abson, & Härdtle, 2016) e de como os modelos econômicos lineares e ecológicos opõem-se (Hauff, 2016).

2. 2. Educação Ambiental

A Educação Ambiental é tema que deve ser inserido desde o início da vida do cidadão para que ele entenda que faz parte de um ecossistema e que suas ações são determinantes para o bom funcionamento e equilíbrio de todas as espécies que fazem parte desse sistema, e uma vez que ele não entende seu papel e suas responsabilidades, o homem coloca em xeque toda a sobrevivência de gerações futuras e de preservação das espécies existentes.

No Brasil, a Lei 9.795 versa sobre a Educação Ambiental, e o Art.1º posiciona a mesma como uma ferramenta da qual o indivíduo e a coletividade edificam seus valores acerca da preservação do meio ambiente, e o uso responsável do que provem da natureza, essencial a qualidade de vida e a sustentabilidade. Em seu Art. 2º a lei institui que a educação ambiental é um componente curricular essencial, e deve estar presente em todos os níveis e modalidades do processo educativo, ou seja, a escola é o local onde esses princípios de preservação e cuidado, assim como a responsabilidades de nossas ações devem ser abordados para que os cidadãos estejam cientes de seus deveres e direitos acerca do tema, para que uma vez instruídos consigam levar a teoria para fora dos muros da escola, e colocar em prática por meio de ações responsáveis.

Conforme Thomazi e Bento (2013) a educação ambiental surge a partir de uma resolução importante durante a Conferência organizada pela Organização das Nações Unidas em Estocolmo na Suécia, onde o objetivo era colocar o problema ambiental no centro das discussões, e onde ficou estabelecido que o cidadão deve ser educado com potencial transformador, onde o mesmo deverá educado para solucionar os problemas por ele mesmo causa ao meio ambiente. Os autores consideram a educação ambiental emancipatória ideal, pois vai além de instigar os alunos a se envolverem o tema, pois existe a quebra do paradigma onde o aluno a partir do entendimento do seu papel muda

seu comportamento e passa a interagir a favor da causa através da participação social, e a partir do momento que o tema é evidenciado nas escolas existe o envolvimento muito além somente de alunos, pois engloba também corpo docente e comunidade.

Dessa forma, a Educação Ambiental assume uma postura transformadora, onde a responsabilidade do educador é de construção e orientação do uso de ferramentas para que esses indivíduos saibam usa-las como instrumento de uma prática relacionado ao bem-estar do mesmo, pois o homem tem dependência direta com a natureza, e uma vez que os alunos têm conhecimento construído acerca do tema, capacita o mesmo para mudanças de comportamento.

2. 2.1. Educação Ambiental Sustentável

A questão ambiental é um dos pilares da Sustentabilidade e, como tal, o processo educacional não deve ser omitido quando se trata de um processo de conscientização social. Seguindo esta abordagem (Roorda & Son, 2016) enfatiza que a educação deve desempenhar um papel essencial para o desenvolvimento sustentável.

Para o autor, Educação para o Desenvolvimento Sustentável se dá quando a universidade atua como uma organização de aprendizado, tendo como premissa a criação de um conjunto de disciplinas ao longo do período de formação que estejam voltadas para as questões ambientais, ou seja, com reflexos diretos no currículo educacional. Para além disso, enfocam como esta questão se relaciona com o papel da universidade no que diz respeito ao tipo de formação dada e sua contribuição ao campo profissional.

Contudo, a questão da educação não deve começar pelo topo e sim pela base, com ações de longo prazo que devem começar ainda no início da carreira educacional do indivíduo (Kirchherr & Piscicelli, 2019). Com efeito, os conceitos relacionados com a educação para desenvolvimento sustentável (ESD) têm sido discutidos como forma de elevar o pensamento crítico do cidadão, de maneira que possa avaliar e tomar ações voltadas para estas questões (Morad, Wade, & Vickery, 2015).

Conforme atesta (Andrews, 2015), o aprendizado sobre a sustentabilidade, a partir de um processo educacional, pode influenciar as ações futuras do indivíduo, delineando seu comportamento de encontro à estas questões. Iniciativas voltadas para o desenvolvimento de ações vinculando a educação com os processos circulares e sustentáveis têm se tornado mais frequentes, e revelam que novas metodologias podem

contribuir para este processo de ensino-aprendizagem voltadas para as questões circulares e de sustentabilidade de forma integrada (Rodríguez-Chueca, Molina-García, García-Aranda, Pérez, & Rodríguez, 2020).

2. 3. Projeto de Produto

Para alcançar o objetivo de criar um produto, deve-se realizar um conjunto de atividades que possibilite chegar as especificações de projeto de um produto e de sua produção, para que a manufatura seja capaz de produzi-lo e isso é chamado de Processo de Desenvolvimento de Produto (PDP) (ROZENFELD et al., 2006).

Há várias metodologias utilizadas para desenvolver um produto que são chamadas de modelos de referência, que servem como um guia na estruturação do PDP. Ou seja, esses modelos podem ser usados como base para a criação de outros modelos, pois o conteúdo necessário para elaborar um projeto de produto varia do tipo de projeto como, por exemplo, se o projeto for simples, o modelo consequentemente deverá ser simples.

O modelo mais relevante para essa área é o do Rozenfeld et al. (2006), que dividiu o PDP em três macrofases: pré-desenvolvimento, desenvolvimento e pós-desenvolvimento. No geral, esse processo é dividido em gates ou fases, visando facilitar o controle e entendimento das atividades necessárias a serem realizadas para obter o produto final.

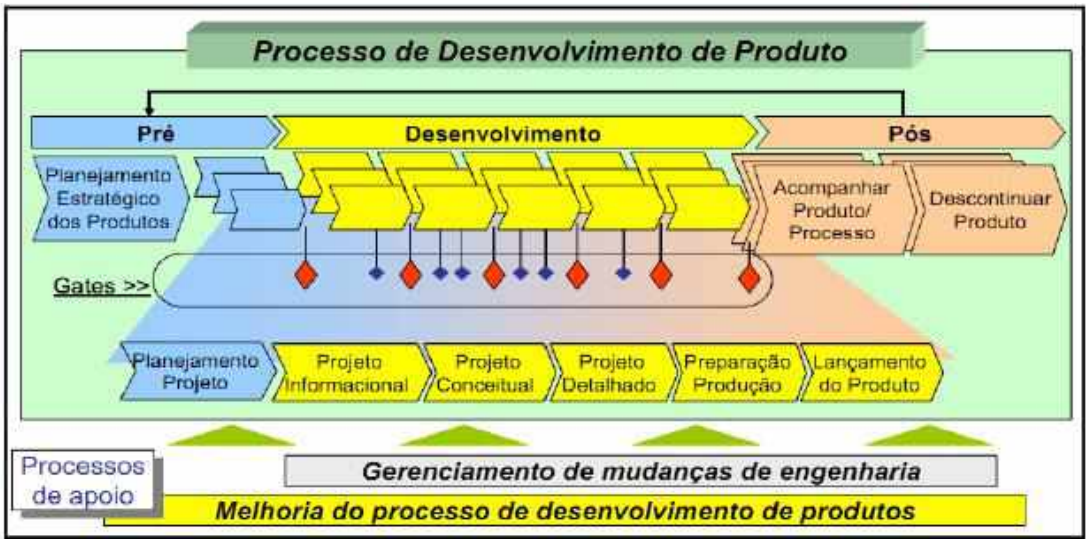

Figura 3 - Modelo de PDP.
Fonte: (ROZENFELD et al., 2006)

2. 3.1. Projeto de Produtos Circulares

De acordo com Franco (2019), um produto é considerado com um design circular quando é projetado para permanecer em um estado mais próximo do produto original e a qualidade do material deve ser mantida e o desperdício é evitado. Para além disso, segundo o autor, determinará os poluentes e resíduos despejados no meio ambiente, a energia que consumirá e a facilidade de reintroduzir os componentes de um produto nos ciclos de fabricação.

Para projetar um produto que não agride o meio ambiente, é essencial escolher cuidadosamente os materiais e tecnologias durante a fase conceitual, porque é o estágio crítico do processo de desenvolvimento de novos produtos e as decisões mais importantes são tomadas (Relich & Pawlewski, 2018; Franco, 2019).

Mestre & Cooper (2017) avaliam que os aspectos de qualquer produto, design e material podem contribuir para o esgotamento de recursos, a deterioração dos ecossistemas e as preocupações com a saúde humana. Nesse sentido, um produto que atenda a metas sustentáveis se caracteriza por melhorar as soluções em sua vida útil, promovendo a desmaterialização e aumentando sua ecoeficiência. Os autores sustentam que, no desenvolvimento de produtos, existem oito etapas que se aproximam do design ecológico e são aplicadas em um ciclo de vida do produto que ajuda a entrar em conceitos de design circular: *seleção de materiais de baixo impacto, redução do uso de materiais, otimização de técnicas de produção, otimização de sistemas de distribuição, redução do impacto durante o uso, otimização da vida útil inicial, otimização do sistema final da vida útil e novo conceito de desenvolvimento*.

CAPÍTULO 3 – Metodologia da Investigação

O trabalho de investigação de pós-doutoramento iniciou com uma pesquisa de cunho teórica, etapa a qual compreendeu o levantamento de informações bibliográfica com respeito aos conceitos de educação ambiental, economia circular, sustentabilidade e projeto de produtos circulares e, posteriormente, na publicação de artigos explorando os resultados obtidos.

As etapas da pesquisa são apresentadas na Figura 4.

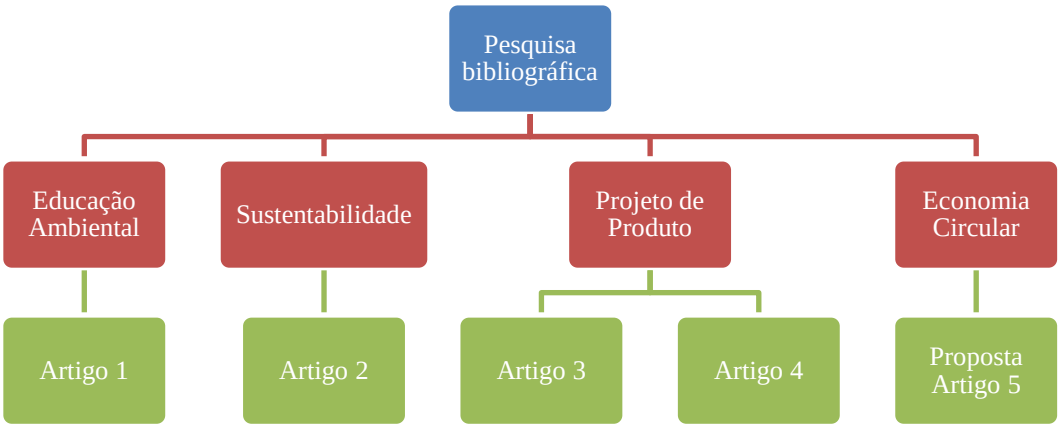

Figura 4 - Campos de estudo x Resultados.

3. 1. Percurso Metodológico

Para o presente trabalho, a metodologia proposta será de caráter exploratório, para entendimento da situação atual, ou seja, qual o nível de instrução que os docentes possuem acerta de coleta seletiva e descarte correto, e de que forma essa como essa informação é passada aos discentes de forma teórica na escola para que se tornem ações transformadoras da situação atual.

Dessa forma, para entendimento e posterior intervenção as etapas abaixo estão propostas:

- No primeiro momento, será entendido como a escola aborda o tema Educação Ambiental e de que forma esses conceitos estão sendo levados para os jovens para que se tornem ações práticas de aplicação direta no dia-a-dia.
- Será proposto um questionário para que os discentes para compreender como se dá seu relacionamento com o consumo, descarte e encaminhamento dos resíduos produzidos por esse indivíduo;

Pretende-se, ainda, no âmbito deste projeto de investigação, , avaliar os processos produtivos de duas empresas do polo industrial de Manaus. Na empresa de pequeno porte pretende-se avaliar as etapas relacionadas com o processo produtivo e de como este se relaciona com os preceitos da Economia Circular. Na empresa de grande porte pretende-se propor ações de redução de impacto ambiental a partir da utilização de resíduos provenientes do processo produtivo para a concepção de um produto.

Nesse contexto, a economia circular inspira formas alternativas de modelos de negócios que abordam a sustentabilidade e a sua relação de equilíbrio com o desenvolvimento econômico, ambiental e social. Apesar disso, não é muito debatido academicamente em diferentes áreas a não ser na literatura sobre negócios e sustentabilidade (MURRAY et al., 2015).

Devido a essa limitação acadêmica existente na E.C., decidiu-se estender esse conceito aplicando-o na prática em um produto, pois é necessário ampliar a preocupação ambiental desde o momento da idealização de um produto.

A forma utilizada para selecionar um produto fora guiada pelas três categorias técnicas para a geração de ideias proposta pelo (BAXTER, 2011), as quais são:

- Redução do problema: examinam os componentes, características e funções do problema, tentando resolvê-lo, modificando uma ou mais características. Essa técnica somente focaliza a atenção sobre o produto existente e nada além dele;
- Expansão do problema: explorar ideias além do domínio imediato do problema. Procura alargar as perspectivas do problema, ampliando a uma gama de soluções a serem aplicadas no produto;
- Digressão do problema: procura fugir do domínio imediato do problema. Essa técnica pode começar com o problema original e é estimulado incursões laterais ou o contrário.

A partir da problemática previamente apresentada, a categoria técnica a qual se enquadra o presente trabalho é a de expansão do problema, pois o objetivado é propor soluções a todo tipo de produto quanto a aplicação da Economia Circular.

Elaborando a parte estratégica do produto, deve-se alinhar a missão, objetivo, ações a serem tomadas e como implementar as ações com base nos ideais da economia circular. As questões a seguir fazem parte de uma técnica proposta pelo Baxter (2011) e estão alinhadas a um planejamento estratégico de desenvolvimento de produtos.

3. 2. Local da Pesquisa

O desdobramento da pesquisa se dará em três etapas, conforme os agentes participantes:

- Escola pública municipal Padre Mauro Fancello situada na cidade de Manaus, no bairro São Francisco;
- Escola pública municipal Frei Silvio Vagheggi situada na cidade de Manaus, no bairro Praça 14 de Janeiro;
- Microempresa que atua no processamento de produtos de madeira;
- Empresa do polo industrial do setor de higiene pessoal e produtos descartáveis;
- Empresa do polo industrial do setor de produtos descartáveis.

3. 3. Natureza da Pesquisa

Para a concretização dos objetivos traçados para este trabalho, quanto a natureza do tipo de pesquisa, o presente estudo recorrerá, em primeiro momento, à pesquisa bibliográfica, a fim de embasar conceitos e direcionar a prática, seus objetivos elencados e, por fim, a pesquisa aplicada, com intuito de adquirir ou gerar novos conhecimentos para a concretização dos objetivos traçados para este trabalho.

Quanto à natureza, o presente estudo recorrerá a natureza qualitativa, com a aplicação de uma pesquisa ação, com intuito de as ações e sua conformidade com os preceitos da economia circular.

3. 4. Instrumentos e Procedimentos da Pesquisa

Relativamente às ações na escola pública municipal, na fase da aplicação dos questionários, os respondentes inicializarão o preenchimento individual dos questionários, apontando e pontuando suas particularidades quanto às práticas adotadas

para o uso e descarte de materiais, visando avaliar sua percepção em relação ao ambiente e sua correlação com a adoção de práticas como fruto de etapas voltadas para a educação ambiental.

Com respeito à microempresa, pretende-se avaliar os processos de produção e sua aderência aos conceitos preconizados pela economia circular. Já para a empresa de grande porte, pretende-se realizar uma proposta de concepção de um produto, que seja de uso prático e de fácil concepção, a partir dos resíduos gerados ne fase de manufatura de lápis de colorir.

3. 5. Base de Dados da Pesquisa

O presente trabalho foi composto por revisão bibliográfica, abrangendo estudos já realizados sobre o assunto, como artigos publicados em periódicos, livros e sítios da internet. A análise qualitativa e quantitativa foram feitas a partir das respostas aos questionários e entrevistas.

CAPÍTULO 4 – Resultados

O trabalho de pós-doutoramento proposto consistiu na realização de um projeto de investigação acerca das práticas relacionadas com a adoção da economia circular e suas relações nas perspectivas da educação ambiental, sustentabilidade e projeto de produtos circulares.

Nesse sentido, de acordo com as etapas previstas no plano de estudo, artigos com os resultados foram publicados em periódicos indexados à Scopus e ISI, identificados na Tabela 3, estando em anexo as publicações originais realizadas e devidamente publicadas.

Título	Periódico	ISSN	Data Publicação	Indexing
Environmental Education as a strategy to foster Circular Economy	International Journal of Current Research	0975-833X	Março 2020	ISI
Circular Economy and its strategic role in education: A qualitative and quantitative approach	International Journal of Development Research	2230-9926	Junho 2020	ISI
Entrepreneurship Education for the development of a new product and process methodology based on circular economy	Journal of Entrepreneurship Education	1098-8394	Junho 2020	Scopus
Product development proposal following the principles of circular economy: a case for a company in the Manaus industrial hub	CENTERIS - ProjMAN - International Conference on Project MANagement	Procedia Computer	Artigo aprovado para conferência em Vilamoura, Algarve, em 21 a 23 de outubro 2020.	Scopus
The Circular Economy from Woodshop Perspective: A case study inside Amazon	Sustainability	2071-1050	Em fase de reavaliação por parte dos revisores	Scopus

CONCLUSÃO

É notório que a evolução nos processos industriais, desde o que conhecemos como primeira revolução industrial até ao momento atual, que denominados de Indústria 4.0, ou quarta revolução industrial, que a abordagem de maior relevância tem seu foco nos processos e sua evolução, desde o emprego maciço de mão de obra (substituindo os processos mecanizados) até o uso da inteligência artificial (substituindo a mão de obra) como forma de evidenciar os avanços obtidos.

Contudo, os aspectos relacionados com a sustentabilidade e preservação ambiental não foram pilares relevantes para a afirmação e consolidação dos modelos preconizados pelas conhecidas revoluções industriais. Considerando o estágio atual, embora as Indústria 4.0 dê suporte para os pilares da economia circular (reuse, recycle and reduce - 3R's) , ainda assim a discussão e ações desenvolvidas não são suficientes quando se aprofunda a questão da sustentabilidade e limitação dos recursos.

Entretanto, num momento de profunda reflexão mundial, com cenários que levam à restrição de recursos, mão de obra e matéria, impôs-se, naturalmente, a necessidade de se discutir todo o modelo de produção até então empregado, que passa pela concepção de novas formas de hábito de consumo e redução compulsória do uso dos recursos naturais nos processos produtivos.

A necessidade de reinvenção nos leva a uma nova forma de conviver e de reaprender, e reforça as questões básicas voltadas para a conscientização e nosso processo de formação e educação. É nesse contexto que se desenvolve este trabalho, que explora a percepção dos hábitos de consumo de alunos de uma escola pública e sua relação com ambiente, postura e hábitos diários, mostrando a importância da conscientização ainda na formação do cidadão, que será alcançada por meio de políticas educacionais que privilegiam a educação ambiental como ponte para a sociedade baseada no consumo excessivo se transformar numa sociedade baseada no consumo sustentável.

Este trabalho buscou identificar a importância da formação educacional como forma de entendimento dos processos preconizados pela economia circular sem, no entanto, querer explorar o domínio deste assunto por parte dos estudantes da escola que participou do projeto, mas sim de compreender sua percepção sobre dois importantes pilares que compõem e são afetados pelo conceito de sistema circular: o meio ambiente e a sustentabilidade.

Conceitos sobre resíduo sólido e lixo não estão bem claros, e a pesquisa revelou que 59,1% dos alunos não sabem diferenciá-los. Para além disso, quando se avalia a composição curricular nas escolas e como as temáticas ambientais se fazem presente nas discussões acadêmicas em níveis mais iniciais, percebeu-se que cerca de 50% dos alunos não associam a discussão de temáticas ambientais com ações voltadas para a educação ambiental, embora entendam que discussões sobre o assunto sejam importantes e que se preocupam com o meio ambiente e com a preservação dos recursos naturais. Contudo, cerca de 11% dos alunos consideram que os recursos naturais são infinitos e outros 86,4% sustentam que seus hábitos de consumo não causaram impacto ambiental.

Com respeito aos hábitos e senso de responsabilidade, os alunos entendem, por exemplo, que a coleta seletiva é importante e necessária, mas que é função do poder público realizá-la e entendem que não são responsáveis pela gestão do lixo que geram, atribuindo ao poder públicos a responsabilidade por este processo.

Nessa questão foi possível observar que apenas 48% dos respondentes possuem algum entendimento sobre coleta seletiva e deixa oportunidades de poderem compreender os mecanismos circulares e de como a organização comunitária pode criar ações voltadas para geração de renda dentro da comunidade, a partir da reciclagem do material gerado na residência, escola e entorno.

Nesse sentido, a consolidação e entendimento dos conceitos circulares passa pelo fortalecimento de nossa consciência ambiental, da mudança de hábitos e costumes, conforme revelou a pesquisa. Contudo, na grande maioria dos casos, o que se entende não se dá pela formação recebida em anos de convivência na escola, mas sim por práticas empíricas.

A existência de uma sólida política educacional, quando ofertada desde a base, é capaz de impulsionar naturalmente os conceitos preconizados pela economia circular, criando um círculo virtuoso natural para que estes conceitos estejam fortemente

enraizados em todas as camadas da formação educacional do indivíduo. Para que seja eficaz, não deve se limitar apenas aos ciclos de formação superior, que é onde tem sido discutida esta temática nos dias atuais, que produzirão resultados de curto e longo prazos na sociedade, não dependendo de momentos de exceção (pandemias, por exemplo) para provocar a mudança de hábitos na sociedade.

Com respeito aos trabalhos desenvolvidos no âmbito das empresas, percebeu-se que as ações ainda são de pequena monta. Considerando que a região concentra um grande polo industrial, o desenvolvimento de políticas públicas que incentivem as empresas a adotarem medidas circulares e sustentáveis constituem-se em propostas desafiadores a serem levados à cabo pelos órgãos gestores, juntamente com as empresas.

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APÊNDICES

Apêndice 1: Environmental Education as a strategy to foster Circular Economy

Abstract: This paper aims to present a study carried out in a municipal school on the city of Manaus, in the state of Amazonas (Brazil). The proposal was to assess students' perception of the concepts related to education and sustainability and how the circular economy can be boosted in society through consistent educational policies. The methodology consisted of the application of a questionnaire to students of a public school, in order to assess their perception about the environmental theme and the promotion of circular actions, followed by a qualitative and quantitative analysis of the information obtained. As a conclusion from the study, the existence of a solid educational policy, when offered from the bottom up, is capable of naturally boosting the concepts advocated by the circular economy, creating a natural virtuous circle so that these concepts are strongly rooted in all layers of the individual's educational background.

Keywords: *Circular economy, Education for Sustainable Development, Management education.*

Apêndice 2: Circular Economy and its strategic role in education: A qualitative and quantitative approach from the perspective of a public school

Abstract: This paper aims to present a study carried out in a municipal school on the city of Manaus, in the state of Amazonas (Brazil). The proposal was to assess students' perception of the concepts related to education and sustainability and how the circular economy can be boosted in society through consistent educational policies. The methodology consisted of the application of a questionnaire to students of a public school, in order to assess their perception about the environmental theme and the promotion of circular actions. As a conclusion from the study, the existence of a solid educational policy, when offered from the bottom up, is capable of naturally boosting the concepts advocated by the circular economy, creating a natural virtuous circle so that these concepts are strongly rooted in all layers of the individual's educational background.

Keywords: *Circular economy, Education for Sustainable Development, Management Education.*

Apêndice 3: Entrepreneurship Education for the development of a new product and process methodology based on circular economy

Abstract: Designing out waste and pollution as well as keeping products and materials in use and regenerating natural systems are the base for circular economy. This research presents an adapted product development methodology based on a circular economy that objectifies renewable resources and minimizing the production of residues. This new methodology comes from the necessity of modifying the liner model of product development for industries where a product that goes out never comes back. The adapted methodology will be put to the test in a case study product design made from plastic waste, a sub-product from an industry inside the industrial pole of Manaus – Amazon.

Keywords: Circular economy, Product design process, Product methodology.

Apêndice 4: Product development proposal following the principles of circular economy: a case for a company in the Manaus industrial hub

Abstract: This paper aims to develop a product where the concepts related to the Circular Economy has been applied in its development process. The application of the circular economy concept for a product project, in addition to the model-free application, aims to boost the optimization of goods flows, maximizing natural resources and minimizing waste production, while maintaining constant value creation, which moves the product from one chain to another, providing savings to the public sector through the management of this waste, as well as limiting the environmental impact and promoting social actions, from a financial point of view. Planning a product with the present Circular Economy principles has increased creativity and innovation to build new methods that can be applied since the planning stage until the final product comes into the market.

Keywords: Product development; Circular economy; Circular product design; Innovation management.

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RESEARCH ARTICLE

ENVIRONMENTAL EDUCATION AS A STRATEGY TO FOSTER CIRCULAR ECONOMY IN A PUBLIC SCHOOL IN THE STATE OF AMAZONAS

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ABSTRACT

This paper aims to present a study carried out in a municipal school in the city of Manaus, in the state of Amazonas (Brazil). The purpose of the proposal was to assess students' perception of the concepts advocated by the circular economy and how environmental education contributes to circular actions in order to boost the local economy. Since environmental education is a political and pedagogical process, it was intended to assess the lifestyle, consumption habits and values of the students involved and their relationship with their environment. The methodology consisted of the application of a questionnaire to students of a public school, in order to assess their perception about the environmental theme and the promotion of circular actions, followed by an exploratory analysis of the information obtained. As a conclusion of the study, from the premise that the Amazon region is extremely vulnerable to human actions, it was realized that the lack of understanding about the environmental issue is strongly linked to the lack of actions focused on Environmental Management and Education, such as a bridge for clarification, awareness and training of those involved.

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INTRODUCTION

This 20th century was a watershed when issues such as technology and consumption were put in check at the expense of our natural resources, since the rudimentary and artisanal style of production was totally modified by the advent of the industrial revolution. In the last 150 years, we have developed a linear production system, where we remove resources from nature, produce items for our consumption and dispose of at the end of the process. Added to this system, the population in a century has quadrupled, which has resulted in an overload of planet Earth, where today 1.5 planet per year is needed to sustain our consumption habits (Weetman, 2017).

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The United Nations already calls attention to the need for a change in this paradigm, where we need to start organizing the economy in a circular way so that waste is put back into a production chain, and where consumers - the last link in a chain - abandon the idea of using and throwing away (Sustainable Development Goals, 2020). In Latin America, 90% of municipal waste is sent to landfills. Data from the IPEA (https://www.ipea.gov.br/ portal/index. php?option= com_content&view=frontpage&Itemid=61.) record that only 13% of all this solid waste generated is destined for recycling, turning all this potential waste into a product. In Brazil, this percentage is distributed as follows: 50% Organic, 16% Paper, 11% Plastic, 5% Glass, 3% Metal and 13% Others. In this way, it is possible to see where the movement towards a circular economy begins, placing these already processed resources in a new production chain.

The data show urgency, indicating that responsibilities need to be assumed by all links in the chain. The industries need to improve the environmental management of their processes - both by managing their waste in production operations and their policies regarding reverse logistics, and simply looking for solutions that do not generate waste in their distribution. The public agent, through effective public policies, that will boost environmental education, which, in turn, will act as a link for awareness and decision making aiming at the preservation of the ecosystem, being a mechanism for the development of circular policies with sustainability. This work is the result of an Extension Project developed by the Federal University of Amazonas with a Municipal Public School, in order to observe the school's strategies regarding the Environmental Education theme, as this theme is discussed with students (children and youth) and how the school works in this environment. Cycles of lectures were carried out as well as practical activities with the community, regarding to recycling activities and selective collection for sending to recycling companies. The main objective of this work was related to the development of a critical sense to motivate students to change their attitude, to be aware of the impact on the environment according to their behavior and consumption pattern.

LITERATURE REVIEW

Environmental Education: Considering that more recently the concepts of economics have been more widely discussed in teaching environments (Merli, 2017), the environmental issue becomes increasingly relevant, and it is vitally important to make people aware of their consumption habits and systems of production. Higher-education institutions have started to develop academic curricula, research capacity and extension activities that are related to the circular economy seeking to foster such practices through environmental awareness (Mendoza, 2019; Kirchherr, 2019). The themes of selective collection, waste disposal and the consumption of organic products are considered of low relevance to be worked on Environmental Education in municipal schools in Manaus. Thus, the relationship with the very low level of recycling of our solid urban waste is evident, data from SEMULSP show that from January to December 2018, 99% of the waste went to landfill, 0,05% were destined for recycling and 0, 92% were destined for composting (Environment Ministry, 2020; Municipal Secretariat of Urban Cleaning, 2020).

Environmental issues have been discussed worldwide for decades. Despite this, awareness is still insufficient because the problems continue to persist and only increase each year. The environmental problems that were and still were faced in the world have solutions that transcend politics and geographic issues due to their complexity and interdependence (Morad, 2015). One of the tools that can reverse this scenario is education, which is seen as the main lever for generating change. The authors also state that the present education is inefficient, as it is not appropriate for sustainable development and, of course, it leads society to live in an unprecedented way. Education is the key to intervention to bring about changes in values, behaviors and the lifestyle required to achieve sustainable development (Rodríguez-Chueca, 2019) point out that recent graduates which will be inserted in the market for the power to change they will still continue with an unsustainable mentality and will not take decisions based on awareness about sustainability and the environment.

For this reason, (Morad, 2015) emphasize that it is important that educational systems are reoriented towards sustainability, as the next generations will be aware of how their way of life impacts the environment, one that education is essential for having engaged citizens and willing to act in the face of environmental difficulties. Therefore, new forms of learning must be encouraged so that barriers to discipline, and culture of unsustainable thoughts are discouraged (Sandin, 2018; Suárez-Eiroa, 2019; Saavedra, 2017).

Circular Economy: According to (Ellen Macarthur Foudation, 2020) the economic model based on extraction, production and waste that we currently practice is reaching its physical limits. In this context, the circular economy is an alternative to redefine the notion of growth, with a focus on benefits for the entire society, decoupling economic activity from the consumption of finite resources, and eliminating waste from the system on a principle. Supported by a transition to renewable-energy sources, the circular model builds economic, natural and social capital, based on the principles of eliminating waste and pollution from the beginning, keeping products and materials in use and regenerating natural systems (**MacArthur**, 2013; **Ellen MacArthur Foundation, 2020**). In recent years, there has been pressure to accelerate the transition to a more sustainable society, as environmental problems such as, for example, the loss of biodiversity, resource exploitation and the most diverse types of pollution have increased (**Geissdoerfer, 2017**).

According to (Weetman, 2017), from the concepts called Cradle to Cradle, biomimicry, ecosystem services, industrial ecology and over-cycling, drive the concept of innovation for circular actions. Also according to the author, the pillars who support an economic and sustainable vision of society are related to nature conservation; limitation of toxicity; resource productivity; social ecology; cultural ecology. In fact, the concept of circular economy is also associated with that of sustainability, and they are widely disseminated through the initiatives of various entities and researchers (Sandin, 2018; Wilts, 2016; Romero, 2017; Mestre, 2017). In this context, sustainability can be defined as a set of human activities that are conducted without affecting global ecosystems. It is a transformation in the lifestyle of society that optimizes the conditions of well-being and health of the environment, always maintaining the supply of non-renewable materials (Geissdoerfer, 2016).

METHODOLOGY

This work was elaborated from a case study. In this sense, the proposal sought to investigate how the contemporary problem of solid waste is related to environmental education. The research in question was carried out in a public school in the municipal school system, located in the south zone of the city of Manaus in the São Francisco neighborhood, which serves about 450 children between the morning and afternoon shifts, and covers early childhood education up to the 5th year, with children aged 5 to 11 years. In addition to regular activities, the school offers a program called “pit-stop” for school reinforcement for students who have difficulties. The study was carried out in the months of July and August 2019, where, first, the research proposal was presented to teachers, coordinators and pedagogues so that everyone understood the work plan that would be developed at the school.

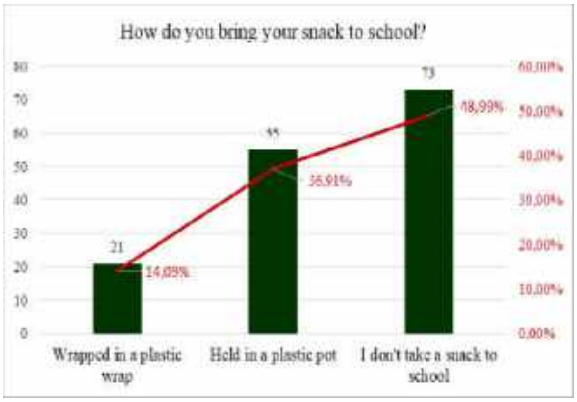

Fig. 1. Plastic utilization

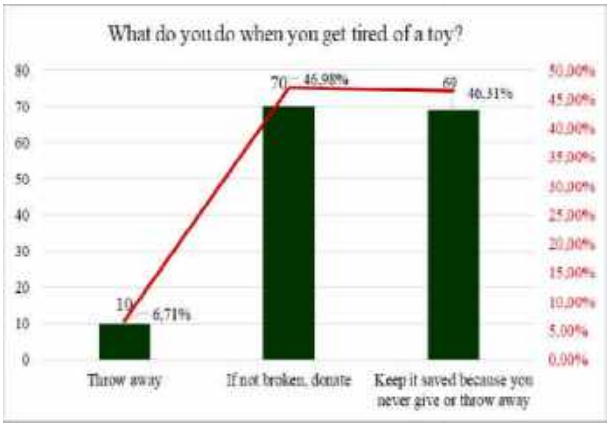

Fig. 2. Posture with respect to the use of toys

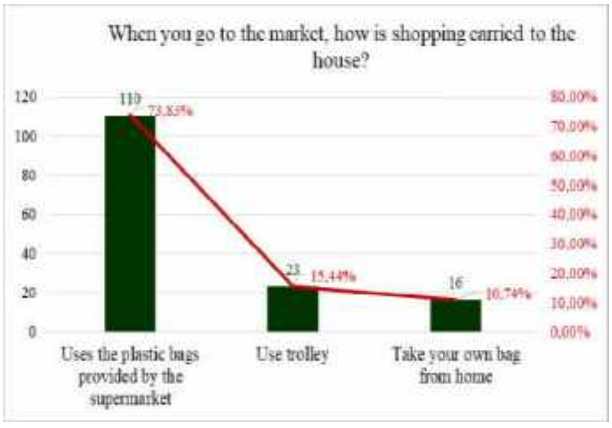

Fig. 3. Habit of using plastic bags in supermarkets

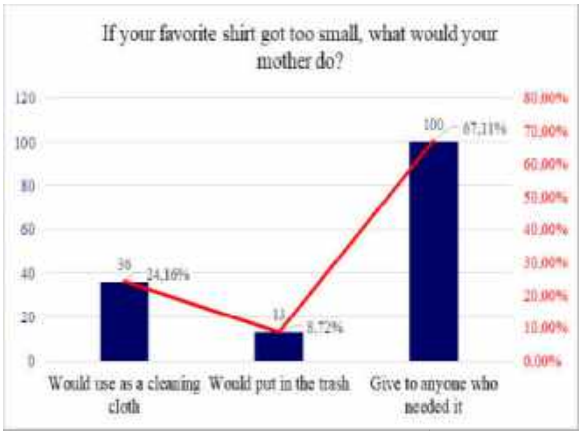

Fig. 4. Habit of using clothes

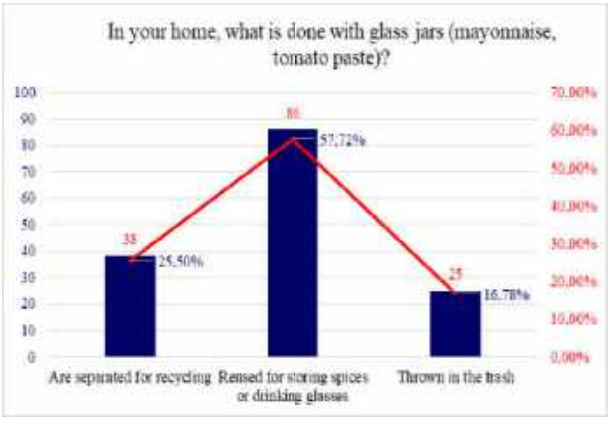

Fig. 5. Use of glass utensils

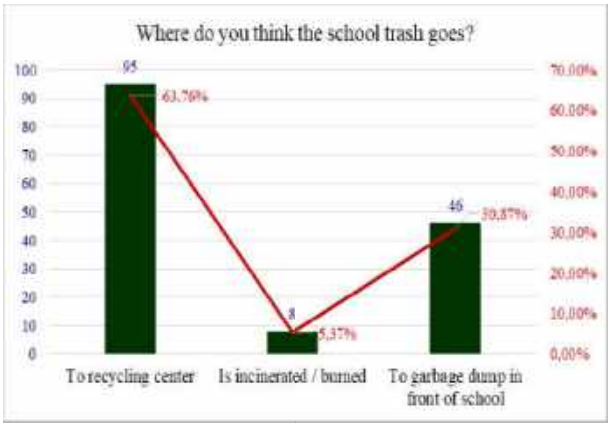

Fig. 6. Waste destination generated at school

Fig. 7. Waste destination generated at student's home.

In a second step, the work was developed by the children, with the application of a questionnaire. The questionnaire was developed for the purpose of understanding how children relate to the solid waste generated both at school and in their home space, what is the understanding of this chain and how they see themselves as part of the process. An amount of 152 students answered the questionnaire, resulting in a rate and response of around 35%. Based on the data obtained, an exploratory study was carried out related to the students' environmental practices. In addition, the physical structure of the school was analyzed in relation to its performance regarding solid waste. The collectors used in the school were verified, both in common spaces and in classrooms. It was also analyzed how the waste produced by the school itself in its operation is discarded, and whether the school has any visual orientation for students or even the existence of class activities related to the theme of environmental education.

RESULT AND DISCUSSION

Next, we evaluate the data obtained in the research and a brief discussion of its content, from those related to the consumption pattern such as those related to the environment. Regarding the question that investigates whether students take snacks to school and how they store them, we have that 48% of respondents say they do not take food from each to school. However, those who claim to take a meal, about 52% use bags or plastic pots, and the bags are thrown in the trash, as shown in Figure 1. Regarding to the question that investigates what students do when they no longer want a toy, we have that 47% of respondents donate them and 46% put them kept. However, about 10% throw toys in the trash, as shown in Figure 2. Regarding the question related to the purchase of products in supermarkets, we have that 73% of respondents use plastic bags offered by supermarkets to store and transport their purchases. Only 10% take their plastic bags to transport their purchases in supermarkets, as shown in Figure 3. Regarding the question related to the use of clothes, we have that 67% of respondents use to donate them when they are no longer used. However, about 24% use them as a household cleaning cloth and 9% throw garbage that no longer serves, as shown in Figure 4. Regarding the question related to the use of utensils made of glass, usually consumer products (soft drinks, food, etc.) that use this type of packaging, we have that, after its use, about 25% of respondents separate them for recycling. However, about 58% reuse it for different applications and 17% throws it in the trash after use, as shown in Figure 5.
Regarding the question related to the destination of the garbage generated in the school, we have that about 64% of the respondents believe that they are sent for recycling. For about 31%, it is sent to containers that exist at the school, in order to be collected for the dump. 5% already believe that the garbage is incinerated, as shown in Figure 6. Regarding the question related to the destination of the garbage generated in the students' homes, we have that about 64% of the respondents believe that they are sent for recycling. For about 31%, it is sent to containers that exist at the school, in order to be collected for the dump. 5% believe that the garbage is incinerated, as shown in Figure 7. Finally, regarding the last question in the questionnaire, in which it is intended to know whether the waste generated in the residence was separated and sent for recycling, we have that about 55% of the respondents reported that the waste was recycled. For 45% of respondents they reported did not separate waste to recycle, believing that this is the responsibility of the public agency.

Conclusion

After the presentation of the theme that this work proposed, the teachers were very willing and engaged to participate in the project, including contributing ideas for the improvement of activities. The first observation of the school structure is the lack of appropriate containers for the selective collection of waste generated by the school's own operation. For example, in the cafeteria where food is produced, a large daily amount of plastic food packaging is generated, organic waste and oil already used in food preparation, which are not disposed of properly. It was also noticed that the students' attitude is to believe that they have no environmental responsibilities, since they understand that this is the role of the public sector. That is, the collection, separation and recycling of materials should be the responsibility of public agents, forgetting themselves that they are the initiating agents of this process. It is a fact that immediate actions to promote new sustainable production models and consumption habits must be implemented. How it takes time, as these are habits developed over many years, and behavioral and cultural change are known to be a slower process of consolidation.

In this context, the emphasis on educational public policies, oriented towards environmental preservation, can assist in the understanding and implementation of the concepts advocated by the circular economy, seeking more sustainable and environmentally correct operations. However, this will not be possible without the development and maturity of the main agents of this process: the human being. Moreover, a space opens up for reflection on the socio-economic-environmental future if these possibilities brought about by circular models are neglected. Actions aimed at environmental education will be the spearhead for the development of research that results in better products, processes and business models. However, its main task will be to promote people's awareness and their role in society, which will happen through education and, in this study, in particular, environmental education.

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RESEARCH ARTICLE OPEN ACCESS

CIRCULAR ECONOMY AND ITS STRATEGIC ROLE IN EDUCATION_A QUALITATIVE AND QUANTITATIVE APPROACH FROM THE PERSPECTIVE OF A PUBLIC SCHOOL

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ABSTRACT

This paper aims to present a study carried out in a municipal school on the city of Manaus, in the state of Amazonas (Brazil). The proposal was to assess students' perception of the concepts related to education and sustainability and how the circular economy can be boosted in society through consistent educational policies. The methodology consisted of the application of a questionnaire to students of a public school, in order to assess their perception about the environmental theme and the promotion of circular actions. As a conclusion from the study, the existence of a solid educational policy, when offered from the bottom up, is capable of naturally boosting the concepts advocated by the circular economy, creating a natural virtuous circle so that these concepts are strongly rooted in all layers of the individual's educational background.

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INTRODUCTION

It is clear that the evolution in industrial processes, from what we know as the first industrial revolution to the present moment, which we call Industry 4.0 (fourth industrial revolution), that the most relevant approach has its focus on processes and their evolution, since the massive employment of labor (replacing mechanized processes) up to the use of artificial intelligence (replacing labor) as a way of showing the progress achieved. However, aspects related to sustainability and environmental preservations were not relevant pillars for the affirmation and consolidation of the models advocated by the well-known industrial revolutions. Considering the current stage, although Industry 4.0 supports the pillars of the circular economy (reuse, recycle and reduce - 3R's), as [Rajput, 2019], even so, the discussion and actions developed are not enough when the question of sustainability is deepened and resource limitation.

However, in a moment of deep global reflection, with scenarios that lead to the restriction of resources, labor and material, it was naturally necessary to discuss the entire production model hitherto employed, which involves the design of new forms of consumption habit and compulsory reduction in the use of natural resources in production processes. The need for reinvention takes us to a new way of living and relearning, and reinforces the basic questions focused on awareness and our formation and education process. It is in this context that this work is developed, which explores the perception of consumption habits of students in a public school and its relationship to the environment, posture and daily habits, showing the importance of awareness still in the education of citizens, which will be achieved through of educational policies that favor environmental education as a bridge for a society based on excessive consumption to

transform itself into a society based on sustainable consumption. This work is the result of an Extension Project developed by the Federal University of Amazonas with a Municipal Public School, in order to observe the school's strategies regarding the Environmental Education theme. The main objective of this work was to show the importance of the actions recommended by circular economics from the educational process.

LITERATURE REVIEW

Circular Economy and Sustainability: The circular economy has been widely discussed as a way to revitalize economic and productive processes from the perspective of reducing impacts on the environment and boosting sustainability. In this sense, the classic definition of CE refers to the contributions of researchers working in this area, and they define it as the replacement of a linear model by a circular model, where residues are inputs for a new process or product that are related in a closed-loop [MacArthur, 2013; Weetman, 2017]. The transition from the linear model to the circular model is supported by a transition to renewable-energy sources, so that the circular model builds economic, natural and social capital and is based on the following principles: eliminate waste and pollution from the beginning, maintain products and materials in use and regenerate natural systems [Ellen MacArthur Foundation, 2017]. However, there are studies that indicate that the systematic of using waste to feed another process does not always result in products with the same level of performance as those made with original raw material [Zink, 2017]. In addition to the ideas of CE need greater scientific support [Korhonen, 2018] and be appropriately measured using appropriate indicators to assess the effectiveness of circular actions [Moraga, 2019; Busu, 2019]. Indeed, the actions recommended by the CE lead us, inevitably, to assess how these actions have a strong relationship with the concepts of Sustainability, since the term is associated with human actions and activities that aim to meet the current needs of human beings, without compromise the future of the next generations [Von Wehrden, 2016; Sustainable Development Goals, 2020]. Moreover, it is discussed how the linear and ecological economic models are opposed [Von Hauff, 2016] and how its premises influence the discussion by adopting circular flows or the immediacy of linear flows.

Sustainable Environmental Education: The environmental issue is one of the pillars of Sustainability and, as such, the educational process must not be omitted when it comes through a process of social awareness. Following this approach [Roorda, 2016] emphasizes that education must play an essential role in sustainable development. For the author, Education for Sustainable Development occurs when the university acts as a learning organization, with the premise of creating a set of disciplines throughout the training period that are focused on environmental issues, that is, with reflex's educational curriculum. In addition, they focus on how this issue relates to the role at the university with regard to the type of training given and its contribution to the professional field. However, the issue of education should not start from the top, but at the bottom, with long-term actions that should start early in the individual's educational career [Kirchherr, 2019]. In fact, the concepts related to education for sustainable development (ESD) have been discussed as a way to raise the critical thinking of citizens, so that they can evaluate and take actions focused on these issues [Morad, 2015]. As attested [Andrews., 2015], learning about sustainability, from an educational process, can influence the individual's future actions, outlining his behavior against these issues. Initiatives aimed at developing actions linking education with circular and sustainable processes have become more frequent, and reveal that new methodologies can contribute to this teaching-learning process focused on circular and sustainability issues in an integrated manner [Rodríguez-Chueca, 2020].

METHODOLOGY

This chapter presents the exploratory study carried out to identify the environmental management practices adopted by the school involved in the work. The study involved a questionnaire, developed based on bibliographic analysis and based on the knowledge of the area, seeking to be comprehensive in the themes, including issues related to all management and environmental education processes, as well as those related to Circular Economy and Sustainability. The questionnaire was sent to the students of the college, covering all grades and the results were analyzed using a descriptive and inductive approach and took place from November 2019 to January 2020. In the descriptive approach, information related to the posture of the school and students regarding environmental management, posture in relation to the circular economy, sustainability, recycling practices, consumption habits, among other environmental aspects were evaluated. In the inductive approach, hypothesis tests were conducted to assess the dependency relationship between environmental education and circular practices, as well as environmental education and sustainability. The questionnaire aimed to identify the practices related to environmental management adopted by the school and students in the context of sustainable actions, recycling, consumption habits and circular systems. The questionnaire consists of open and closed questions, and it is structured in three sections, namely: *Section I - Habits and Posture; Section II - Environmental Education, and Section III - Environmental Management and Sustainability.* The criteria for choosing the school took into account its location (a school in the center of the city was sought, as it is the community where the master's student resides) and, secondly, a school that serves high-school students. The Frei Silvio Vagheggi municipal school agreed to participate in this study and is structured to serve 605 students, distributed in the morning and afternoon shifts with 344 and 261 students respectively. For this work, a cut was made of the 1st afternoon of high school. Three (03) classes of 1st year in the afternoon are offered, serving 91 students, where 67 participated in the survey, making a response rate of 73% of the total students. The average age of the students who participated in the research is 15.45 years and lives in different neighborhoods in the city of Manaus. In addition, as it is an investigation that also relates the habits of students within the family, the number of people living in the same residence was raised, and we obtained an average of five (05) people, with extremes in the order of sixteen (16) people and two (02) people.

RESULT AND DISCUSSION

Exploratory Analysis: This section aimed to investigate aspects related to environmental education, selective collection, the importance of environmental management and the students' attitude towards these current themes. In this sense, with respect to the question that investigates whether the student knows how to differentiate between garbage and solid

waste, we have that 41% say they know the difference between them. Regarding the statement about environmental education, about 76% said they had full knowledge about it. It was also questioned whether there is understanding and understanding about what selective collection is, where about 66% said they had complete understanding. Environmental issues were addressed in this questionnaire. In this sense, we sought to investigate whether recent themes on climate change and themes related to environmental preservation were addressed, where 52% said that such themes were discussed.

Corroborating this question, about 94% of the respondents considered the discussion of these topics important. Aspects related to the practice of selective collection are important in the context of environmental education, circular economy and sustainability. In that sense, these themes were addressed in this questionnaire. Thus, we sought to investigate such actions in the context of the necessary preparation for carrying out these activities. About 52% of respondents reported not knowing how to separate and classify waste for proper selective collection. Corroborating this question, about 83% of respondents said they did not perform such activities within the family. The details of these questions are shown in Figure 1.

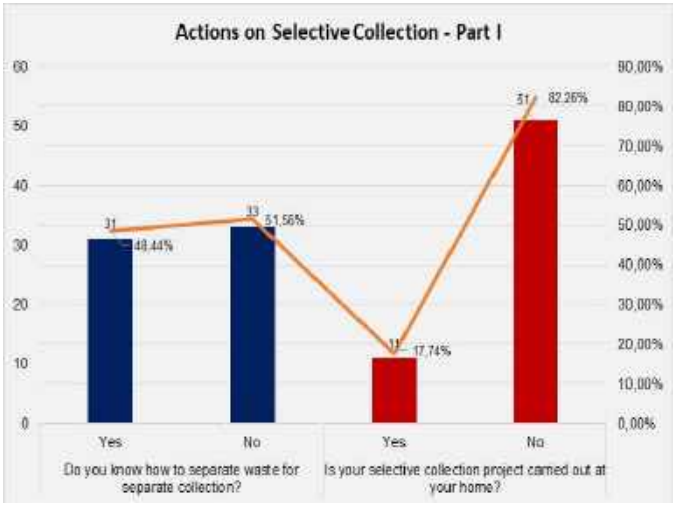

Figure 1. Actions on selective collection – Part I

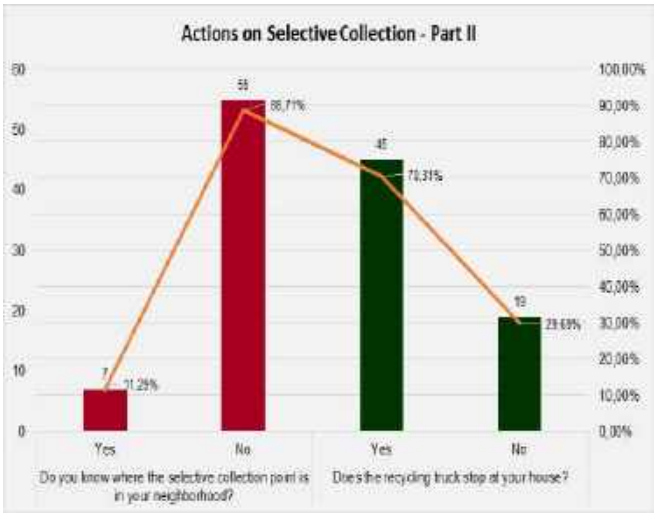

Figure 2. Actions on selective collection – Part II

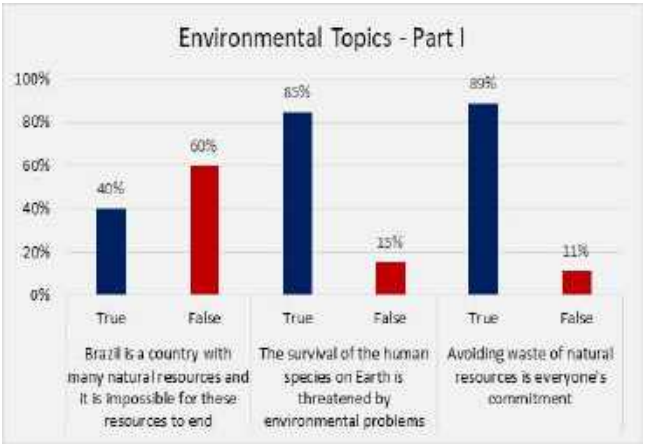

Figure 3. Environmental topics – Part I.

Still in the context of selective collection, knowing that many actions are also due to the existence of public policies, the extent of the adoption of community measures was explored. Thus, we sought to investigate the existence of selective collection points in the neighbourhood where the students live, as well as in the area where the school is located. About 88% of respondents reported not knowing about the existence or location of a selective collection point in their neighbourhood or near surroundings. In contrast to this question, the same group, about 70% of respondents positively affirmed that the garbage collector passes in their neighbourhood, where it was not investigated if it was a common or specialized collection. The details of these questions are shown in Figure 2. Although public policies are relevant factors in the approach to environmental actions, it is important to explore the individual's position in this context. In this sense, individual attitudes were addressed in this questionnaire. With this, we sought to explore the individual's contribution to environmental issues and their performance in the environment. About 87% of respondents reported being concerned with environmental issues and their impacts. Corroborating this question, about 84% of respondents stated that they would participate in initiatives aimed at environmental practices, if invited. However, about 60% stated that they do not feel responsible for the destination of the waste or garbage it generates, believing this to be a function of the public power. In this sense, with respect to the question that investigates the potential of the use and exploitation of natural resources, we have that 60% stated that our resources are not finite. With respect to the issue that relates the exploitation of natural resources and the continuity of species, we have that 85% stated that the burden on the environment can cause future problems due to the impact on the ecosystem and the scarcity of non-renewable resources. Awareness about the preservation of natural resources, as well as their rational use, led us to explore the students' perception regarding the waste of such resources, inputs and products. With regard to the issue that explores everyone's commitment to the rational use of non-renewable resources, 89% said that the commitment not to exhaust the environment must be everyone's commitment. The details of these questions are shown in Figure 3. The role of everyone in society, in view of environmental practices, led us to explore the students' perception of their own performance. Regarding the question that asks about public participation in these actions, 68% stated that the responsibility for the entire waste management cycle, from collection to disposal is the responsibility of the public authorities. Still addressing the issue about the role of

everyone in society, we sought to assess the perception of students with respect for the impact that they themselves have on the environment. With regard to the question that asks how consumption habits impact upon the environment, 86% stated that their actions contributed to the degradation of nature. The details on these questions are shown in Figure 4.

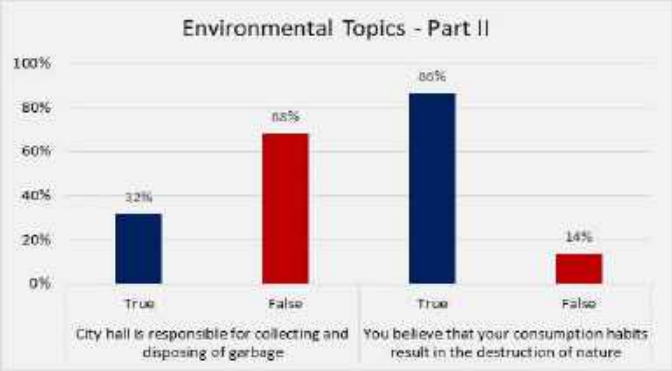

Figure 4. Environmental topics – Part II.

Comparative Analysis: In this first part of the comparative study, it was intended to assess whether the habits and posture of school students have an influence on the perception of environmental education, since the approach to this theme can be a factor that influences the behavior of students at school or at home. Thus, the data were stratified for each of the questions analyzed, and hypotheses were formulated for the performance of comparative tests. The Chi-square independence test was applied to assess the students' response to the questions asked, and the results are presented in Table 1.

H_1. The differentiation of garbage and solid waste is independent of its orientation towards environmental education;
H_2. The discussion on environmental issues is independent of its orientation towards environmental education;
H_3. The importance of discussing environmental issues is independent of its orientation towards environmental education;
H_4. The perception of selective collection is independent of its orientation towards environmental education;
H_5. The degree of concern with environmental issues is independent of its orientation towards environmental education;
H_6. The degree of responsibility for the waste generated is independent of its orientation towards environmental education;
H_7. The preservation of the individual as part of the environmental balance is independent of his orientation towards environmental education;
H_8. The preservation of natural resources is independent of its orientation towards environmental education.

Table 1. Comparative analysis of the habits and posture of students with respect to Environmental Education

Hypothesis	$\chi^2_{(1)}$	*p*-value	Null hypothesis
H_1	4,684	0,030	Reject
H_2	0,554	0,500	Do not reject
H_3	0,210	0,647	Do not reject
H_4	0,616	0,433	Do not reject
H_5	0,013	0,909	Do not reject
H_6	0,056	0,813	Do not reject
H_7	1,846	0,174	Do not reject
H_8	0,058	0,810	Do not reject

As results for each hypothesis:

- Definition of garbage and solid waste is dependent on an adequate understanding of environmental education;
- The discussion on environmental issues is related to an adequate understanding of environmental education;
- The importance of discussing environmental issues is related to an adequate understanding of environmental education;
- The importance of selective collection is related to an adequate understanding of environmental education;
- The importance of selective collection is related to an adequate understanding of environmental education;
- The responsibility for the waste generated is related to an adequate understanding of environmental education;
- The responsibility for the waste generated is related to an adequate understanding of environmental education;
- The responsibility for the waste generated is related to an adequate understanding of environmental education.

Conclusion

This work sought to identify the importance of educational training as a way of understanding the processes advocated by the circular economy without, however, wanting to explore the mastery of this subject by the students of the school that participated in the project, but rather to understand their perception of two important pillars that make up and are affected by the concept of a circular system: the environment and sustainability. Concepts about solid waste and garbage are not very clear, and the survey revealed that 59.1% of students do not know how to differentiate them. In addition, the curriculum composition in schools is almost evaluated and as environmental themes are present in academic discussions at earlier levels, it was noticed that about 50% of students do not associate the discussion of environmental themes with actions aimed at environmental education, although they understand that discussions on the subject are important, and that they are concerned with the environment and the preservation of natural resources.

However, about 11% of students consider that natural resources are infinite, and another 86.4% maintains that their consumption habits did not cause an environmental impact. With respect to habits and a sense of responsibility, students understand the selective collection is important and necessary, but it is the function of the government to carry it out and understand they are not responsible for the management of the waste they generate, attributing to the public authorities the responsibility for this process. In this question, it was possible to observe that only 48% of the respondents have some understanding about selective collection and leave opportunities to be able to understand the circular mechanisms and how the community organization can create actions aimed at generating income within the community, from the recycling of material generated in the residence, school and surroundings. In this sense, the consolidation and understanding of circular concepts involve strengthening our environmental awareness, changing habits and customs, as revealed by the research. However, in the vast majority of cases, what is understood about such concepts is not due to the training received in years of coexistence at school, but to empirical practices. The existence of a solid educational policy, when offered from the bottom up, is capable of

naturally boosting the concepts advocated by the circular economy, creating a natural virtuous circle so that these concepts are strongly rooted in all layers of the individual's educational background. To be effective, it should not be limited to higher-education cycles, which is where this topic has been discussed today, which will produce short and long-term results in society, not depending on moments of exception (pandemics, for example) to bring along a change in habits in society.

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ENTERPRENEURSHIP EDUCATION FOR THE DEVELOPMENT OF A NEW PRODUCT AND PROCESS METHODOLOGY BASED ON CIRCULAR ECONOMY

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ABSTRACT

Designing out waste and pollution as well as keeping products and materials in use and regenerating natural systems are the base for circular economy. This research presents an adapted product development methodology based on a circular economy that objectifies renewable resources and minimizing the production of residues. This new methodology comes from the necessity of modifying the liner model of product development for industries where a product that goes out never comes back. The adapted methodology will be put to the test in a case study product design made from plastic waste, a sub-product from an industry inside the industrial pole of Manaus–Amazon.

Keywords: Circular Economy, Product Design Process, Product Methodology.

INTRODUCTION

It is known that society, since the beginning, has used these resources was only a function of subsistence. Later, it was transcended to satisfy basic needs and began to aim at making a profit. During the First Industrial Revolution, which started in England in the 18th century, there was a milestone in the consumption of natural resources. Steam engines were created to replace and improve previous models of goods production. These machines worked through the combustion of mineral coal and were initially applied in the textile industry and later expanded to other segments. In the second half of the 19th century, the Second Industrial Revolution began, it brought novelties to the civilization, such as the invention of light and the discovery of oil and the combustion engine. From this industrial rise it is possible to affirm that each year, 6 million hectares of productive land become a desert (Keeble, 1988), causing a reduction in natural resources availability (Ahuti, 2015; Nelliyat, 2005) and increase in consumption of energy and waste per inhabitant.

One way of establishing sustainable development is by applying methodologies that cause the least amount of environmental damage and that consume the least amount of natural resources, especially if they are non-renewable. The purpose of this work is to apply the circular economy in a project where the flow of goods is optimized, minimizing the waste products as well as using assets that were considered by other companies as trash, in addition to always

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maintaining a constant creation of value that moves the product from one chain to another. This article will have a brief literature review and will propose a new product development methodology considering the circular economy and sustainable engineering.

LITERATURE REVIEW

To achieve the goal of creating a product, a set of activities must be carried out that makes it possible to reach the design specifications of a product and its production so that the manufacture can produce it and this is called the Product and Process Development (PPD) (Rozenfeld & Amaral, 2006). There are several methodologies used to develop a product, reference models, as they are usually called. These models can be used as a basis for the creation of other models since the content needed to elaborate a product can vary.

One of the most complete and relevant models in this area is one proposed by Rozenfeld & Amaral (2006), and this model divides the product development into three macro phases: pre-development, construction and post-development. In general, this process is divided into gates or phases to facilitate control and understanding of the activities necessary to be carried out to obtain the final product.

In the first phase, the goal is to choose what the product will be as well as its shape before starting to develop it. It is important to well define all the main points of configuration in this macro phase to avoid problems later (Browning et al., 2006). Pre-development should ensure the strategic direction, product ideas, opportunities, and restrictions are mapped out and transformed into actions to develop a product. (Baxter, 2018; Rozenfeld & Amaral, 2006) states that the following steps must be taken: strategic product planning and product planning.

The second phase begins from the macro definition of the product elaborated in the previous stage; this part has five steps: Informational Design; Conceptual Design; Detailed Design; Preparation of product production and Product Launch. The post-development phase monitors the product life cycle until its decline, that is when the product is removed from the market, and all measures for the disposal of the material must be taken (Faria et al., 2008). In addition, information such as product results on the market; of production; distribution; customer service; and technical assistance (Baxter, 2018; Rozenfeld & Amaral, 2006).

CIRCULAR ECONOMY

According to Craft (2004), many industries have been applying programmed obsolescence to their products and this means that producers are deliberately designing products that fail prematurely or that become outdated so that consumers purchase a new product or an update. Some industries still make the repair of their products unfeasible, which further strengthens consumerism and, consequently, the contribution with the waste of raw material and pollution. In contrast to this problem, there is the development of the 4th Industrial Revolution that *"leveraged digital technology and advances in new technologies that include the Internet of Things, 3D printer and robotization, creating new opportunities in how resources and products are used and consumed"* (De Angelis, 2018).

EC occurs when the flow of materials involved in the production of a product are biological nutrients that are designed to enter the biosphere safely or, also, technical nutrients that are designed to circulate in high quality in production systems, so that it does not enter the biosphere and its regeneration and restoration is possible (Romero & Rossi, 2017). The scope for

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applying this EC concept is in the Circular Product, which, according to Ellen MacArthur Foundation (MacArthur, 2013), is the result of a design that can significantly reduce the list of materials and expenses with waste. The authors (Bocken et al., 2016) state that there are different strategies that can slow down the resource consumption loop when the product is designed to have a long life, and also when it is possible to extend its life through easy repair.

METHODOLOGY

Circular economy inspires alternative forms of business models that address sustainability and its balanced relationship with economic, environmental, and social development. Despite this, it is not widely debated academically in different areas except in the literature on business and sustainability (Murray et al., 2017). Due to this academic limitation in EC, it was decided to extend this concept by applying it combined with the product and process design methodology presented in the literature review and to show how it is going to work it was put into practice in a product since it is necessary to increase environmental concern from the moment of the idealization of a product.

Based on the Pittaway et al. (2004), the review of the literature was carried out according to the systematic review process in order to link innovative initiatives with partners and boosting cooperation with each other. In addition, Centobelli et al. (2018) contributed with propositions to support university initiatives to become entrepreneurial universities, once the proposed project in this work refers to the search for innovative solutions for the proper destination of residues generated in the productive process of the studied company.

One of the techniques that help generate ideas for selecting a product was guided by the three categories of problems that may be present in a product (Baxter, 2018), which are:

1. Problem reduction: examine the components, characteristics, and functions of the problem, trying to solve it, modifying one or more features. This technique only focuses attention on the existing product and nothing else.
2. Expansion of the problem: exploring ideas beyond the immediate domain of the problem. It seeks to broaden the perspectives of the issue, expanding to a range of solutions to be applied to the product.
3. The digression of the problem: seeks to escape from the immediate domain of the problem. This technique can start with the original question and is encouraged by lateral incursions or the other way around.

From this, the special category in which the product of the present research fits is to propose solutions to all types of products regarding the application of the circular economy.

A determining factor in the choice of the product's raw material was thought through the problem of one of the substances that most cause adverse impacts on the environment, which is plastic. According to the UN (2018):

- Every year, 8 million tons end up being dumped in the ocean and makeup about 90% of the total waste in this area, harming 600 marine species, of which 15% are threatened with extinction.
- If current trends continue, in 2050 the oceans will have more plastic than fish.
- More plastic has been produced in the last decade than in the past century and half of the plastic consumed by humans is disposable (and preventable).

From this, it is evident the need to reduce the consumption and dismissal of materials and, as a way of applying the CE, contaminated polystyrene (PS) residues from an industry located in

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the Industrial Pole of Manaus were assigned to carry out the research, way that an alternative to use this material is found.

RESULTS AND DISCUSSION

To amplify the circular economy concepts a new step inside the pre-development phase, new discussions towards the decision on what the material will be is raised, this polystyrene material comes as a sub product out of pencils being manufactured. For the design of the products it was thought of something simplistic, because the focus of the product is not on its visual perception. Therefore, they have symmetry, harmony and simple lines, giving a minimalist design. The design of the products was carried out in CAD in order to enable the manufacture of the prototype on the 3D printer (Figure 1).

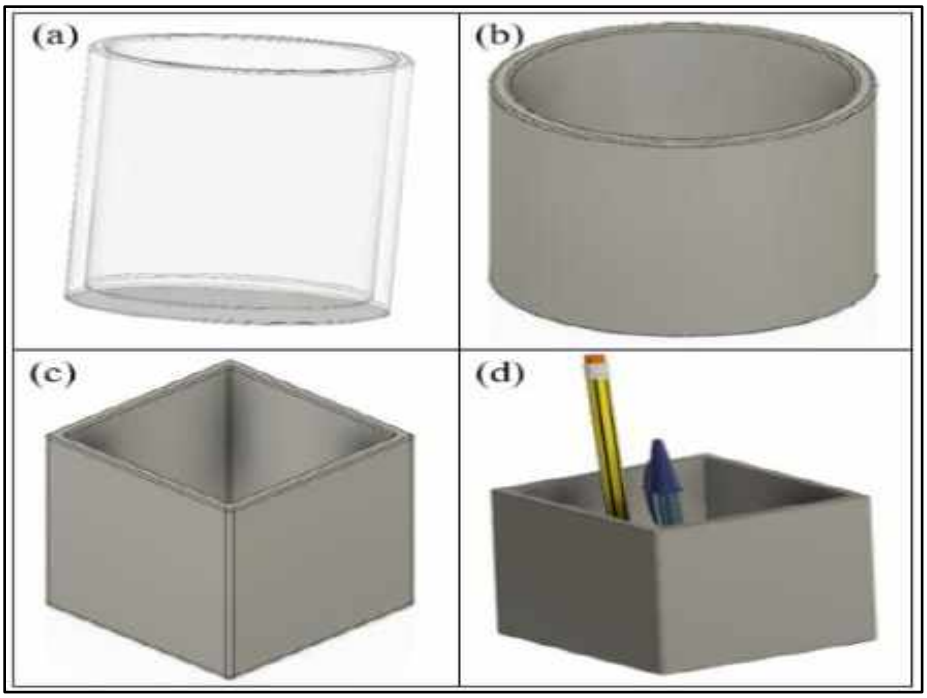

FIGURE 1
3D PRINTER

A parametric analysis could be carried out to compare parameters related to environmental concerns between the proposed products and the product on the market (Table 1).

Table 1
RESULTS FOR A PRODUCT

Parameter	Variable	Product	Difficulties	Target
Container	Material	Polystyrene	Moderate difficulty to be recycled	Contaminated polystyrene container percentage
Recipient	Percentage of recyclable material	0%	Raise the rate of recyclable material	Create a solution to make contaminated plastic recyclable

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CONCLUSION

Through the application of the concept of circular economy in the design of a product, there is an incentive to search for new ecological and innovative alternatives, as it stimulates the generation of questions, such as:

- What kind of waste could be reused, and how would you make it possible? It is known that some materials are not recyclable and alternatives to reverse this scenario must be found. The current solution for them is landfills and incineration, both destinations cause damage to nature.
- What is the best manufacturing method to be used? One must take into account which residues are generated during the processes and if wastes are created, how they can be reused.
- Furthermore, one can think about how to transform technology from a manufacturing method to clean technology, if it is not.
- What is the option to carry out product tests and prototypes that least cause adverse impacts on the environment? It is essential that the least amount of energy is consumed and that waste is minimized, it is added that the products manufactured in this phase must minimize the amount of material and must have an appropriate final destination.

Based on this, these questions help in the evolution of sustainable industries, and it is inferred that its application during the pre-design phase of a product reflects in the industrial symbiosis, as it aims at the use of the residues produced in a process to *"feed"* another method and, also, in the well-known European eco-design directive which aims to make new products more energy efficient. Furthermore, it is reflected in green factories since there are efforts to maintain growth, however, sustainable, since resources (including waste) are used efficiently and, in general, it is thought of strategies that minimize waste generated by-products and processes.

The limitations of the project are related to the infrastructure due to the need for equipment for the development of the project, although the company has committed itself to provide the necessary resources, including the waste generated in the process. As opportunities, we have the possibility of new products from a circular perspective as part of the company's portfolio.

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Product development proposal following the principles of circular economy: a case for a company in the Manaus industrial hub

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Abstract

This paper aims to develop a product where the concepts related to the Circular Economy has been applied in its development process. The application of the circular economy concept for a product project, in addition to the model-free application, aims to boost the optimization of goods flows, maximizing natural resources and minimizing waste production, while maintaining constant value creation, which moves the product from one chain to another, providing savings to the public sector through the management of this waste, as well as limiting the environmental impact and promoting social actions, from a financial point of view. Planning a product with the present Circular Economy principles has increased creativity and innovation to build new methods that can be applied since the planning stage until the final product comes into the market.

Keywords: Product development; Circular economy; Circular product design; Innovation management.

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1. Introduction

It is known that society, since the beginning, has used environmental resources to satisfy its needs. At first, the use of these resources was only a function of subsistence, and later it was transcended to fulfill mere needs and began to aim at profit.

During the First Industrial Revolution, which started in England in the 18th century, there was a milestone in the consumption of natural resources. Steam machines were created to replace the previous model of goods production. These machines worked through the combustion of coal and were initially applied in the textile industry and later extended to other segments. In the second half of the 19th century, the Second Industrial Revolution started to expand to other nations, brought novelties to civilization such as the invention of light, the discovery of oil and the combustion engine. From this industrial rise, it appears that:

- There was a reduction in natural resources as well as an increase in carbon emissions, pollution, and health problems [1].
- There was a reduction in the natural space, an increase in the use of energy and waste per inhabitant [2].
- In each year, 6 million hectares of productive land become a desert; acid rains kill forests and damage architectures inherited from nations and burning fossil fuels increased global warming [3].

It is also noted that not only the industries have contributed significantly to the degradation of the environment, but also the population growth that has encouraged the rise in demand to supply their needs [[4]. In short, the development of society became increasingly unsustainable, generating concern for scientists.

Only from the 1960s, with the publishing of the book A Silent Spring and with the Club of Rome, the concern with the environment took on greater dimensions. At the beginning of environmental movements, the report "The Limits to Growth" was launched, in which it had been pointed out that the unbridled growth of the population would lead to the depletion of natural resources within a hundred years. However, it is stated that is possible to reverse this situation if this growth is slowing down, and if the world's population is aware of environmental problems, the chances of success would increase [5].

In the 1980s, environmental awareness went worldwide with the publication of the "Our Common Future" report, also known as the Brundtland Report. In 1972, at the United Nations Conference on the Human Environment, human rights were outlined in three main aspects: the right to adequate food, clean water and to decide the size of their families. From this premise, the concept of sustainable development emerged, where it was confirmed that humanity can do sustainable development to ensure that it meets the present needs without compromising the ability of future generations to meet their own needs. In addition, it complements that technology and social organization can be managed and improved to drive a new era of economic growth [3].

Given the importance of establishing sustainable development in society, the idea of circular economy (CE) arose. In general, this business model seeks circularity in the use of materials and energy in product design [6]. Hence, it became an important path to succeed in sustainability [7] and sustainable issues must be present since the beginning of a project from any type of organization [8]. Thereby, every new product in the market should consider sustainable issues. In this study, CE concepts will be approached properly and implemented into practices, allowing making a product based on Circular Design principles, and this will help to understand the current application of this business model [9] and can develop innovative alternatives that, e.g. enables to reintroduce waste into the productive chain and to design a product that could be remanufactured.

2. Theoretical background

2.1. Circular Economy

Many industries have been applying planned obsolescence to their products, and this means producers are deliberately designing products that fail prematurely or become out of date for consumers to purchase a new product or upgrade. Some industries still make the repair of their products unfeasible, which further strengthens consumerism and, consequently, the contribution with the waste of raw material and pollution [10].

In contrast to this problem is the development of the Fourth Industrial Revolution, which leveraged digital technology and advances in new technologies that include the Internet of Things, 3D printer and robotics, creating

new opportunities in how resources and products are used and consumed [11]. In addition, the CE system emerges, which brings an approach that incorporates environmental concerns about economic development and according to the industrial ecology concept, CE basis is to preserve economic and environmental utility and value of materials at their highest level as long as possible, either by extending lifetime or by applying a closed-loop of components in a product [12].

That is, in a closed-loop, the waste becomes as a new input for new processes, thus reducing the need for raw materials and, in contrast, exists the open-loop model where products became waste at end-of-life [12]. CE promotes greater proficiency of resources, reducing waste and pollution. From that, it appears that the transition to CE goes beyond linear economy model, that consists of extracting, processing, consuming and dumping [13]. In opposition to linear economy model, we have the CE that is not only about to change the way the products are designed, but is also about to change the way they are commercialized and consumed [12]. Although radical changes must be taken, according to [13] it is possible to implement the CE model, due to constant technological advances which society provides.

CE occurs when the material flows involved in the production of a product are: biological nutrients that are designed to enter the biosphere safely, in other words, the materials "can decompose without causing harm to the environment and provide a source of food for the wider system" [14]. Technical nutrients that refers to closed loops, where inorganic or synthetics materials can be reused without losing their value and are designed to circulate in high quality in production systems, in a way that does not enter the biosphere and its regeneration and restoration are possible [14], [15]. It is important to treat materials in this way so that their period of use is extended and so that the thought of becoming a regenerative and advanced product is encouraged [16]. The Circular Economy can be based on three conceptions [17], [15].

- When there is a need for resources, the circular system selects technologies and processes that use renewable resources, or else it follows the principle of industrial symbiosis which, instead of the waste generated by a process being destroyed or dumped into the environment, can be used as an input for another process.
- Design products for remanufacturing, renovation, and recycling so that the waste or resource takes on a new form of value to increase its productivity, efficiency, and waste reduction. In addition, the useful life of the products must be prolonged, and all materials (nutrients) of a product must be chosen based on recyclability nature and the safe reinsertion of biological nutrients into the biosphere for decomposition should be encouraged.
- Reduce damage to any element of the environment.

A strategy for implementing Circular Economy is the ReSOLVE Structure, which consists of six actions, which are regenerated, share, optimize, loop, virtualize and exchange [[17].

Table 1: ReSOLVE framework [17].

Phase	Actions
Regenerate	Shift to renewable energy and materials. Reclaim, retain, and restore health of ecosystems. Return recovered biological resources to the biosphere.
Share	Share assets. Reuse/secondhand. Prolong life through maintenance, design for durability, upgradability, etc.
Optimize	Increase performance/efficiency of product. Remove waste in production and supply chain. Leverage big data, automation, remote sensing and steering.
Loop	Remanufacture products or components. Recycle materials. Digest anaerobically. Extract biochemicals from organic waste.
Virtualize	Dematerialize directly and indirectly.
Exchange	Replace old with advanced non-renewable materials. Apply new technologies (e.g. 3D printing). Choose new product/service (e.g. multimodal transport).

2.2. Circular Product Design

A product is considered with a Circular Design when it is engineered to be remain in a state closer to the original product and material quality is to be maintained, and waste is avoided [12].

To design a product which is ecological friendly, it is essential to choose carefully the materials and technologies during the concept phase, because it is the critical stage of new product development process and the most important decisions are taken [18], [12].

Consequently, it will determinate the pollutants and wastes dumped in the environment, the energy it will consume, and the easiness to reintroduce the components from a product in the manufacturing cycles [12].

Aspects of any product, design and material can contribute to the depletion of resources, deterioration of ecosystems and human health concerns [19]. Therefore, a product that meets sustainable goals is characterized by improving solutions in its lifetime, promoting dematerialization and increasing its eco-efficiency [19].

In product development, there are eight steps that approach to eco-design, and it is applied in a product life cycle that helps to get into circular design concepts: selection of low impact materials, reduction of material's usage, optimization of production techniques, optimization of distribution systems, reduction of impact during use, optimization of the initial lifetime, optimization of the end of the life system, and new concept of development [19].

According to [12] two strategies characterize a product with a circular design:

1. Slowing loops: it includes designing for longevity and designing for ease maintenance and repair [12], "resulting in a slowdown of the flow of resources" [20]. It is known that most of the physical products wear tear and deteriorate with age and use. Due to cost and technological considerations, it is almost impossible to design a product that is maintenance free [21]. However, as asserted previously that a product should be designed for longevity and design for maintenance, CE model still requires the lifetime maximization of products and materials [12] and this suggests that products should keep their initial value for a longer period, even before being recycled [22]. Thus, if a product has an inappropriate design of quality and reliability it will consequently need more maintenance requirements to compensates for deficiencies [21]. To ensure the desired long-life product performance, the design can be facilitated by maintenance and repair; upgrading and upgradability; standardization and compatibility [20]. These concepts must be defined right from the beginning of development process and should be oriented towards a design that allows generating revenue by creating, delivering, capturing, and maintaining value [12], [21]. This strategy contrasts to the programmed obsolescence, where a product is designed for a shorter lifetime.

2. Closing loops is related to recycling [20] and includes designing for disassembly and reassembly. The core for this strategy it is the ease of disassembly. A product designed for disassembly bring efficiencies in remanufacturing, maintenance or servicing, and recycling and provides some benefits as: recycling time reduction because the product will consume less time to sort, clean and process its parts; increase the fraction of recyclable materials in a product because the parts can be efficiently separated and reused [12]. Furthermore, it is significant to have a technical component part of a product that enables to be recycled into high-quality raw materials to be reintroduced in manufacture [12]. [19] points out that eco-efficient materials have six important features: "green resource profile; minimal environmental impact during their production; high productivity in use; minimal hazardous substances; high recyclability; and high environmental purification efficiency". The post-use product must be returned to the manufacturing, in this way it will result in a circular flow of resources [20]. Therefore, the closed-loop strategy focuses on optimization of any resource consumption, and waste minimization, where the outputs belonged to one process serve as an input for another process [19].

3. Methodology

The goal of this research is to apply the concepts of circularity and consider sustainable issues in the development process of a new product. Within the qualitative approach, bibliographical research of scientific papers and books was carried out to make interpretations about the topics and patterns that emerge from the data [23]. The current CE features was collected, especially the practices and methods to explore and understand the meaning of this business model that was originated from the arise of sustainable development.

The way used to select a product was guided by the three technical categories for generating ideas [24], which are:

- Problem reduction: examine the components, characteristics, and functions of the problem, trying to solve it, modifying one or more characteristics. This technique only focuses attention on the existing product and nothing else.
- Expanding the problem: exploring ideas beyond the immediate problem domain. It seeks to broaden the perspective of the problem, expanding to a range of solutions to be applied to the product.
- Digression of the problem: It seeks to escape from the immediate domain of the problem. This technique can start with the original problem and is encouraged by lateral incursions or the other way around.

The technical category which the present work fits are expanding the problem since the aim is to apply the current solutions to achieve in sustainability in all types of products through CE.

Besides that, it has been prepared a strategic planning of the product to delineate the actions to be taken and how to implement it, all aligned with the ideals of the circular economy.

The following questions are part of a technique to make a strategic product development plan [24] (Table 2).

Table 2: Product strategic management.

Where we are?	In a scenario where it is dominated by the linear economy, it is important to promote the transition to a circular economy and apply it into a product or service.
Where we will go?	Propose a product design that is inside the circular economy, using all the requirements that this business model brings.
How we get there?	Exploring the current research that approaches concepts, methods, and practices and applying it in a new product creation.
How we know we got there?	Through prototypes development and evaluating the performance of product, especially the recyclability of the material.

Beyond that, the selected strategy of Circular Product Design was the closing-loop, since one of the focuses is to recycle material and enable reuse. Then, the material received to propose the new product is a contaminated residue that belongs from a color pencil manufacturing process.

The original product is already conceived from recycled material, and the pencil body is not wood but polystyrene.

The final residue is composed of synthetic resin, granulated powders, and plastics.

Following these premises, brainstorming was used in order to define what type of product would be possible to remanufacture from these leftovers of the production process and then, the chosen product was planned following a method which helps to identify activities, resources and the best way to integrate them [25] and it was modeled according to the design developed and to the CE requirements. In the final phase, a prototype was built using a 3D printing.

The mold and a sample of the product were developed for each of the proposed designs.

4. Results

In order to make the product planning, the following method was adopted to ease the product planning proposal [25] (Table 3). The proposed model for this project is shown in the Fig. 1.

Table 3: Product planning.

Product Scope	The chosen product is a storage dispositive of items, and it has two shapes: a circular and a quadratic one.
Project Scope	• Project context: the patterns from Linear Economy of use and discard products on environment must be broken, and the concepts from Circular Economy must be adopted. An important factor in the moment to choose the material that will compose the product was because the plastics are one of the materials that most causes negatives impact on the environment. In every year, 8 million tons of plastic are thrown up in the ocean. After analyzing the options of use and functions which the product would have, it was chosen an application related to the origin of the residues, (residues from a pencil manufacturing process) which consists of a pen/pencil holder for daily use. • Product description: For the design of the products, it was thought of something naive since the focus of the product is not on its visual perception. Therefore, they have symmetry, harmony, and simple lines, giving a minimalist design. The design of the products was carried out in CAD, to enable the manufacture of the prototype on the 3D printer (Figure 1). The dimensions of the circular product are diameter = 9,0 cm, length = 10,0 cm, and thickness = 0,5 cm; the dimensions of the quadratic product are length = 10,0 cm, breadth = 9,0 cm, and thickness = 0,5 cm. The material to produce this product came from residues of recycled polymer collected in a process of color pencil manufacturing provided by an industry localized in the Industrial Pole of Manaus. • Manufacturing process description: steel molds are necessary.
Prototype	It will be used 3D printer.
Premises, limitations, and restrictions	• Manufacturing must have renewable or cleaner technologies to reduce waste generation during processes. • Reduce pollution and energy consumption. • Use waste generated by a process as an input for another process. • Design for recycling and durability. • Avoid the need for raw material. • Use closed-loop strategy with technical nutrients. • The product components must be composed of residues. • Limited quantity of material (residues) that reduces the production capacity.

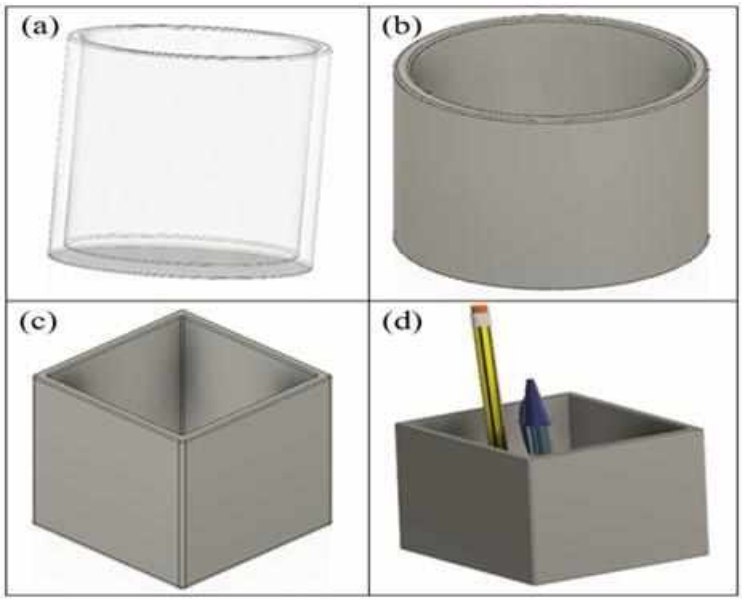

Figure 1: Figure (a, b) demonstrates the product with circular shape, and figure (c, d) represents the product with a quadratic shape. Both CAD drawings were created on Fusion 360 Autodesk.

A parametric analysis was used to compare parameters associated with environmental concerns between the proposed product and the products available on the market, as shown in Table 4.

Table 4: Parametric analysis.

Parameter	Variable	Competing Product	Comments	Target of the product under development
Recipient	Material	Polystyrene	Moderate difficulty to be recycled	Contaminated polystyrene
Recipient	Percentage of recyclable material	0%	Increase recyclable material	Create a solution for contaminated polystyrene to turn into recyclable

5. Conclusion

Circular economy inspires ecological and innovative alternatives ways to be applied to a product which is developed with a balanced relationship between economic and environment. That was possible because this business model demonstrated it was necessary to expand the environmental concerns from the moment of the idealization of a product at the stage of product in the market.

This deepens our reflection on the role of the circular economy and how to make the processes effectively sustainable, and it allows to discover new ways of how waste can be used and transformed into a raw material for a new product, encouraging some questions as:

- What type of waste could be reused e how to make it possible? It is known that some materials are not recyclable and ways to reverse this scenario must be found. The current solution for them is landfills and incineration, destinations that cause damage to nature.
- What is the best manufacturing method to be applied in processes? Residues are generated during the processes and if residues are generated, how they can be reused. Furthermore, it is important to think about how to transform a technology from a manufacturing method to a clean technology.
- What is the option to carry out product tests and prototypes that cause fewer adverse impacts to the environment? It is essential that the least amount of energy is consumed, and that waste is minimized, it is added that the products manufactured in this phase must minimize the amount of material and must have an appropriate destination.

Based on this, these questions help in the evolution of sustainable industries, and it is inferred that its application during the design stage of a product reflects in the industrial symbiosis because the goals are to make use of the residues produced in a process to “feed” another process and, also, in the well-known European eco-design directive which aims to make new products more energy efficient.

Furthermore, it is reflected in green factories since there are efforts to maintain economic growth, however, sustainable, because resources (including waste) are used efficiently and, in general, it is thought of strategies that minimize waste generated by products and processes.

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